

# SHEET AND PLATE METAL WORK



$t k$ , to meet in the point  $c$ . This will give the apex of the cone of which  $t 3$  may be considered to be the half-base. On  $t 3$  describe a quarter-circle and divide it into three equal parts, dropping perpendiculars from each division

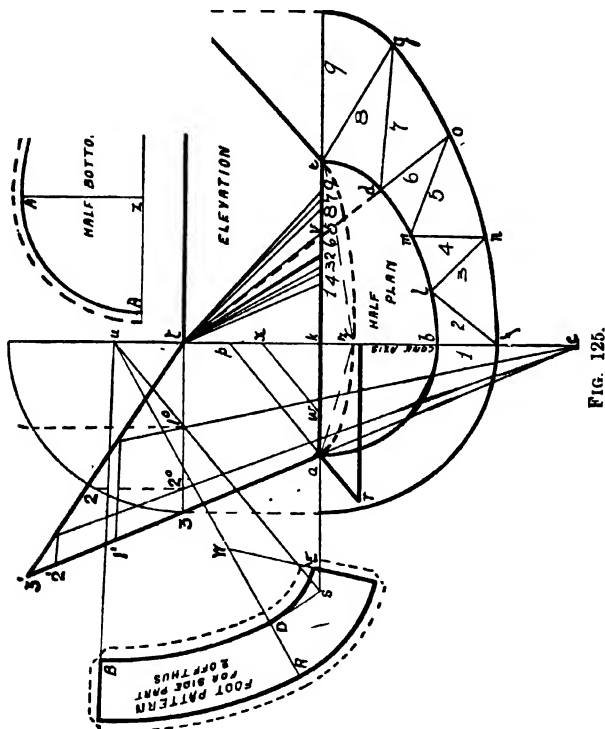


FIG. 125.

point on to the line  $t 3$ . Join  $c$  to each of the points  $1^0$  and  $2^0$  and produce to meet the top line of the back  $t 3'$ . The pattern for the half-cone is now developed by using  $c 3$

as a radius, and setting along a girth line (Fig. 126) equal to twice the length of the quarter-circle in the elevation. Radial lines are then drawn, passing through C and each numbered point on the girth line; these being cut off equal to the corresponding lengths taken from the eleva-

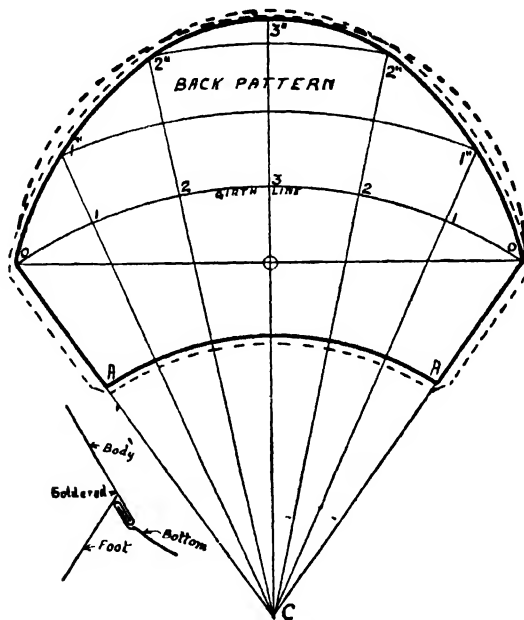


FIG 126.

tion. Thus  $C 1''$ ,  $C 2''$ , and  $C 3''$  are respectively equal to  $c 1'$ ,  $c 2'$ ,  $c 3'$  from the elevation. The points are joined up with a curve and thus will give the outline for the top part of back pattern. The radius  $C A$  for the bottom part will be taken from  $c a$  in the elevation. Allowances are put on the pattern for an edge, to which the bead is attached, a



lap on the sides for grooves, and a single edge for the knock-up around the bottom. When worked up, the back, as set out, will come level across the top; in practice, however, the shoulders are brought round a little, and to do this the upper portion of the back pattern is very often formed by describing a semicircle on the line  $O O$ . The thick dotted line shows this semicircle on the pattern in Fig. 126. It will be seen that this latter method is much easier for marking the back pattern out, and gives a bolder look to the bath when made.

If it is required to make the bath so that the top of the back is to come some other shape, then all that is necessary is to draw an elevation of the particular shape, instead of the line  $t 3'$ . The construction lines  $c 1^0$ , etc., would then be run up to meet this curve.

Instead of marking the side pattern (Fig. 123) out by the methods shown in Chapter XVIII. in connection with oblique cone surfaces, it will be simpler, in this example, to strike it out by the general method of triangulation. Turning

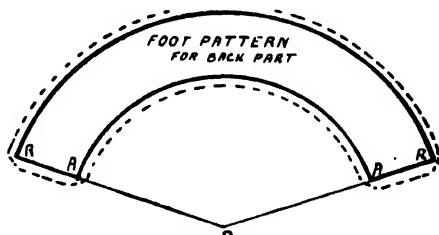


FIG. 127.

again to the plan and elevation in Fig. 125, the curves  $b d$  of the bottom and  $f g$  of the top are each divided into three equal parts, and the lines numbered 1, 2, 3, etc., drawn, thus dividing the plan of the side and half-end into eight triangles. Imagine these are the plans of triangles, which lie on the surface of the bath, and it will readily be conceived that the pattern for this part can be obtained by adding together the true shapes of the eight triangles. To get the true lengths of the sides of the triangles set each

of the numbered lines along from  $k$ , as shown. That is, make  $k$  1,  $k$  2,  $k$  3, etc., equal respectively to the lines numbered 1, 2, 3, etc., on the plan. These points are then joined to  $t$ , and the lengths of lines for the pattern will be measured from the respective points up to  $t$ . Now turn to the side pattern (Fig. 128). Line number 1 is set down equal to  $1 t$ , line number 2 equal to  $2 t$ , and  $B L$  equal in length to the curve  $b l$  on the plan. The length  $F N$  equals  $f n$ , and the line number 3, or  $L N$ , equals  $3 t$ , and so on for the other six triangles. When the points are connected up and the proper allowance added, as in the back plate, the pattern is complete.

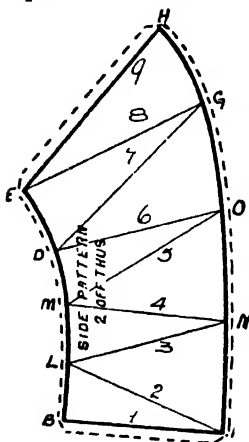


FIG. 128

quarter-circle  $a b$  in plan. The side pattern of the foot (Fig. 125) is developed by first marking off  $k s$  equal to  $t d$  (the point  $t$  in this case being the centre from which the side curve of egg-shaped oval is described), and then drawing  $u s$  parallel to  $p a$ . The curve  $S B$  for the pattern is described with radius equal to  $u s$  and the part  $D B$  cut off equal in length to the arc  $d b$  in the plan. The distance  $k w$  is now set along the same length as  $e v$  (the radius for the

The foot being equal-tapering can have its pattern struck out with very little trouble. The radius for the part of foot to go around the back of bath will be taken from  $p a$ . So that, on the pattern (Fig. 127),  $P A$  equals  $p a$  and  $P R$  equals  $p r$ ; the length of the inner curve  $A A$  being equal to twice the length of the

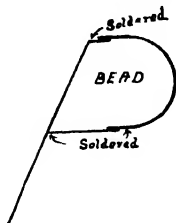


FIG. 129.

now set along the same length as  $e v$  (the radius for the

small end of oval) and  $xw$  drawn parallel to  $pa$ . The centre  $W$  is determined by setting  $DW$  equal in length to  $xw$ ; the arc  $DE$  then being drawn from this centre and cut off the same length as the curve  $de$  in the plan. The width of the pattern will, of course, be the same as that for the back part, that is,  $DR$  will equal  $ar$ .

Allowances must be put on to both the foot patterns to cover for grooving at ends, wiring at bottom and for slipping over the knock-up on bottom of bath.

A pattern, showing the half-bottom, is drawn at the top of Fig. 125; the lines  $ZA$  and  $ZE$  being respectively equal in length to the lines  $za$  and  $ze$  on the elevation. Allowance for a double edge is made all

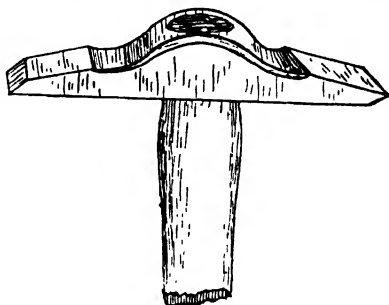


FIG. 130

round the bottom to cover for knocking up on to the body.

A sketch, showing the arrangement of body, bottom, and foot, is shown at the lower part of Fig. 126. A good deal of care wants exercising in attaching the bottom to the body. After the bottom has been hollowed to the proper shape a flange about  $\frac{1}{2}$  in. wide should be set down all round. A single edge is then turned up to fit on the edge around the bottom of bath. After the bottom is slipped on, the paning down can be done with a paning hammer (Fig. 130), or, as is more generally the case, with a sheet metal worker's common hammer, as shown in Fig. 131. The knocking up of the joint can, of course, be done in the usual manner on a bench bar or otherwise.

A sketch explaining the arrangement of the bead is also shown on Fig. 129. The bead is usually made from a

strip of sheet metal, being bent and curved in a beading machine. It can, however, be quite easily blocked up to the required shape with a suitable hammer on a lead block.

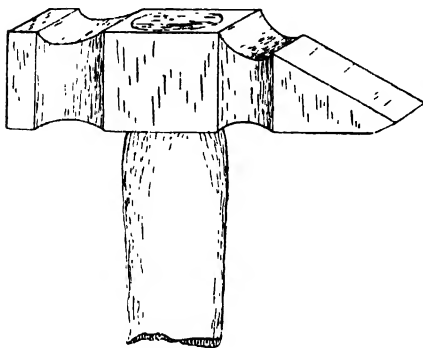


FIG. 131.

It is soldered to the edge of body and filling-in pieces are also soldered to the bead and body, as shown.

Sheet-metal lugs are fastened to the side of bath, as seen in Fig. 124; but these present no difficulty in marking out their shape or making.

### Sponge Bath.

The patterns for a sponge bath (Fig. 132) can be laid out by one or other of the several methods already shown in connection with cone-work. The only part that is not conical and that calls for attention here is the lip or spout. The pattern for this is shown marked out in Fig. 133.

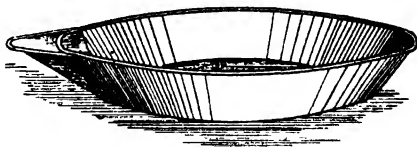


FIG. 132.

An elevation of the lip fitting on to the side of the bath is drawn and also a half-plan, showing the shape of the top of lip. The arc *ab*, on Fig. 133, represents a part of the top of bath. The lip curve is divided into, say, six equal parts, and perpendiculars dropped from

each of the division points, 0, 1, 2, etc., on to the line  $O'6$ . The joint line is then drawn, passing through the point  $O'$ ,

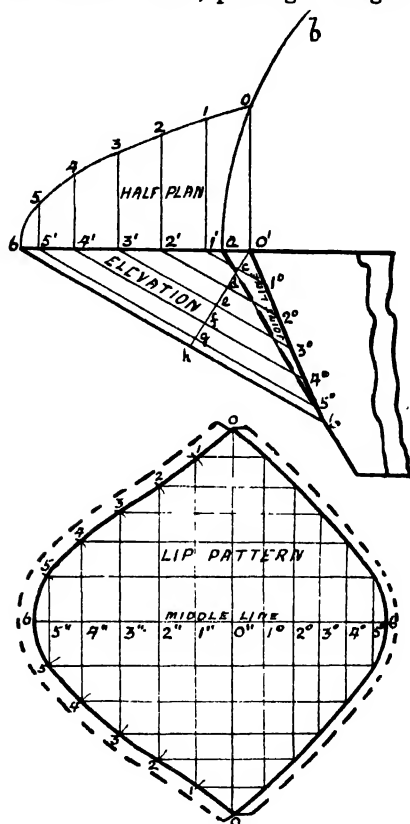


FIG. 133.

as shown. Through the points  $1'$ ,  $2'$ , etc., lines are drawn parallel to  $66$ . For the pattern the middle line is set down equal in length to  $66$  on the elevation, the inter-

mediate points being obtained by making  $0'' 1''$  equal to  $c 1'$ ,  $0'' 2''$  equal to  $d 2'$ , etc.; and then, on the other side of  $0 0$  making  $0'' 1^0$  equal to  $c 1^0$ ,  $0'' 2^0$  equal to  $d 2^0$ , and so on for the remaining distances. Through each of the points on the middle lines perpendiculars are drawn, as shown by the lines  $0 0$ ,  $1 1$ , etc. Now fix the compasses to the length of one of the arcs on the half-plan of lip, and with this distance, commencing at 6 on the life-hand side of pattern, cut off points 5, 4, 3, etc., up to 0. Through each of the points so found draw lines parallel to  $6 6$ , and where these intersect the perpendiculars already drawn through  $1^0$ ,  $2^0$ , etc., will give points on the curve for the right-hand side of pattern. Join these points with a regular curve, add allowances for wiring and a flange, and the pattern is complete.

## CHAPTER XVII.

### OVAL ARTICLES OF EQUAL TAPER.

#### Construction of Equal-Ended Oval.

**THERE** are many articles made out of sheet and plate metal that are either oval or elliptical in shape. Not that these two figures are identical, although they are often confused with each other. The ellipse is a figure in one quarter of which we may suppose every small part of the curve is of a different radius, the curvature of the end being most acute, and the curve becoming flatter as it approaches the middle point of the side of the ellipse. The oval, however, although somewhat similar in shape to the ellipse, is a figure which is built up entirely of arcs of circles. Equal-ended ovals can be drawn by using several arcs of differing radii that are a very good approximation to an ellipse. An oval, however, to the sheet and plate metal worker has distinct properties of its own that make it particularly suitable for use in those cases to which it can be applied. When an article is required to be elliptical in shape, the oval should not be used, as there are convenient methods for the development of this class of work. (Shown in Chapter XXI.)

The most useful shape of oval is that which is made up of *two* different arcs of circles, the one with small radius forming the ends, and the flatter curve joining on to make the sides. This can be set out entirely by construction, or partly by calculation and construction. Both methods will be shown. First by construction: Draw a line A B

(Fig. 134) equal in length to the long diameter of the oval, and through the middle point O of this diameter draw a line at right angles. Make O C and O D each equal to half the small diameter of the oval. From A mark off A E equal in length to C D. Divide E B into three equal parts. Now set the compasses at a radius equal to *two* of the parts, and with O as centre, mark points Q, Q. Then with O again as centre, and the compasses set to length

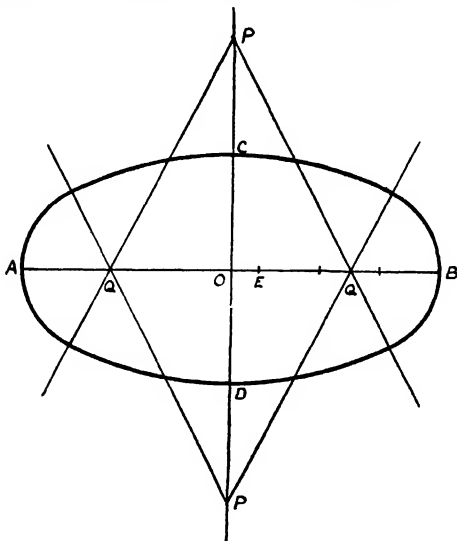


FIG. 134.

Q Q, mark points P, P. It will be seen that O P is equal to *four* of the parts into which E B has been divided. The points Q and P will be the centres from which the arcs will be described. Join P to Q, and produce the lines through as shown. Now with centre Q and radius Q B describe the end arcs, and with centre P and radius P C describe the side arcs. If carefully and properly drawn, the arcs should



meet and run into each other on the lines drawn through P and Q. The object, indeed, for which these lines are drawn is to determine the meeting points of the curves. They also serve another purpose, which we shall see when drawing out the pattern for an oval equal-tapering vessel.

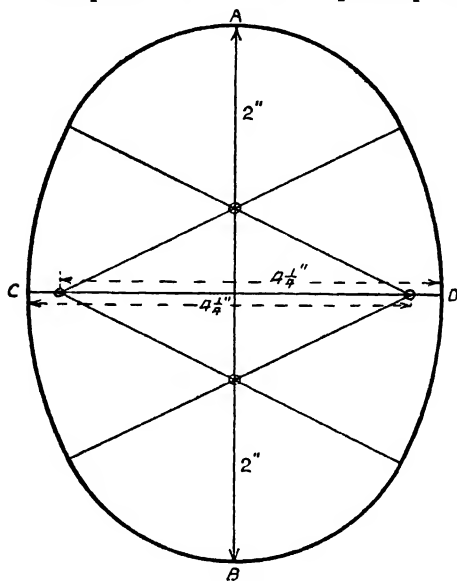


FIG. 135.

It should be noticed that the points P may come either within or without the figure, according as the oval is broad or narrow.

The second method consists in calculating the radii for the arcs and then setting out the figure. The rules for finding the radii are as follows:—

To find radius for sides: "From eight times the long diameter deduct five times the small diameter, and divide the remainder by six." In Fig. 135, the long diameter

$A B = 6$  in., and the short diameter  $C D = 4\frac{1}{2}$  in., therefore the radius for the side is—

$$\frac{8 A B - 5 C D}{6} = \frac{48 - 22\frac{1}{2}}{6} = 4\frac{1}{4} \text{ in.}$$

To find radius for ends: "From four times the short diameter deduct the large diameter, and divide the remainder by six." The radius for the ends, therefore, in Fig. 135 will be—

$$\frac{4 C D - A B}{6} = \frac{18 - 6}{6} = 2 \text{ in.}$$

After having marked the centres, it is generally a good plan to draw in the lines as before, so that the exact point of contact of the curves may be known, as these come in useful later.

The above methods can, of course, only be used in the case of ovals that are the same shape at each end, the egg-shaped oval demanding special treatment.

### Pattern for Oval Articles.

Having gone over the construction of ovals, we can now turn our attention to the development of oval equal-

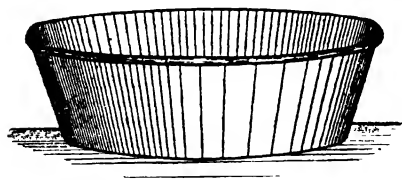


FIG. 136.

tapering articles, or those in which the overhang for the sides is the same as for the ends. Such an article is shown in Fig. 136. It is best to think of the surface of this article as being built up of parts

of the surfaces of two different-sized cones, but whose taper is the same. Thus, referring to Fig. 137, the large dotted circles represent the bases of the cones, part of whose

surfaces go to form the sides of the oval vessel. The small dotted circles show the bases of the cones from whose surfaces the end portion of the oval article is formed. The plan of the axes of these cones, it will be seen, coincides with the points P and Q.

The fitting together of the cone parts is exhibited in

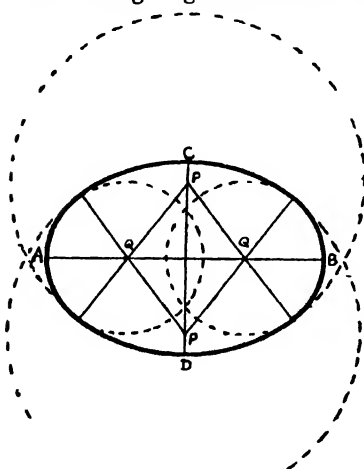


FIG. 137.

plain the fitting together of the side and ends. The three upright lines show the axes of the cones. It should be noticed that the small and large cone surfaces join together in a common line (shown by the dotted lines at the back): hence the two

Fig. 138, which is a sketch of a model showing a part of *one* large cone with the *two* parts of the smaller cones fitting on to form the end portion of the oval object. The front side, which would be the part of the other large cone, it may be imagined, is removed to better ex-

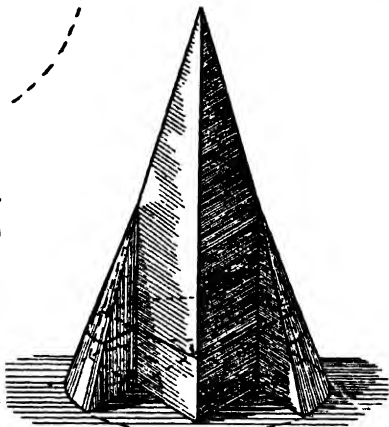


FIG. 138.

curved surfaces fit together without showing lump or hollow. Part of the small oval which forms either top or bottom of the article, as the case may be, is also shown on the model in this figure.

When it is thoroughly understood how the surface of the oval equal-tapering article is built up, the development of the pattern is not at all a difficult matter.

It will, perhaps, be easier to follow if we fix some definite dimensions, and work out the problem completely from these. Thus suppose an oval article is 32 in. by 20 in. at the top, 22 in. by 10 in. at the bottom, and 7 in. perpendicular depth. It should be noted that the dimensions must be such as to give the same overhang all round, and these can be checked by using the following rule:—"The length of bottom deducted from the length of top must be the same as the width of bottom deducted from the width of top." In this case it will be seen that the overhang is—

$$\frac{32 - 22}{2} \text{ or } \frac{20 - 10}{2} = 5 \text{ in.}$$

Calculating the radius for the sides of the large oval by the before-mentioned rules, this will be—

$$\frac{8 \times 32 - 5 \times 20}{8} = 26 \text{ in.}$$

and for the ends—

$$4 \times 20 - 32 \quad 8 \text{ in.}$$

As each quarter of the oval is exactly the same, there is no need only to set out just one quarter, and this can be done in the usual way (Fig. 139). The same centres can be used for marking out the quarter of small oval for the

bottom, the radii for sides and ends being in each case 5 in. less than those used for the top. For purposes of getting out the body pattern, there is really no need to set out the

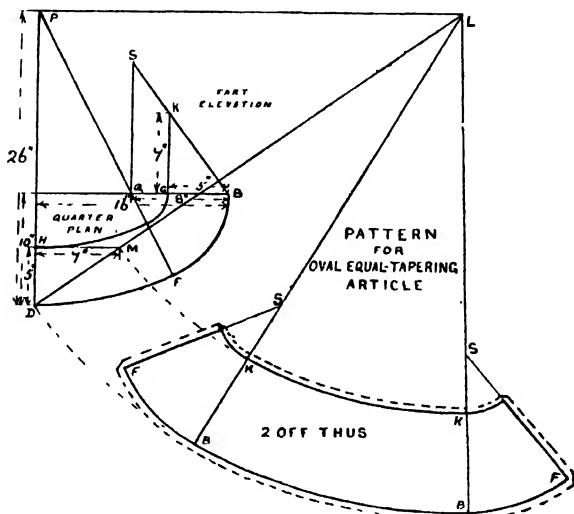


FIG. 139.

quarter-oval for the bottom, its only use being to obtain the size and shape of the bottom plate.

Having marked out the oval, the depth 7 in. should be set up from the point G, and also along from the point H, as shown in Fig. 139. B is joined to K, and produced until it meets a perpendicular through Q in S. Also D should be joined to M and produced until it meets a line which is square to D P in L. By referring again to Fig. 138, it will be seen that the points L and S (Fig. 139) represent the apexes of the large and small cones respectively. Half the

large cone being given as a side elevation on D P, and half the small cone being shown as a front elevation on Q B. The line S B then will give us the slant height of the small cone, and thus the radius for the development of its surface; the line L D serving the same purpose for the large cone.

The pattern can now be struck out. With centre L and radius L D draw an arc, and along it mark off a portion, B B, equal in length to twice the arc D F. Join the points B B to L, then with centre L and radius L M draw the bottom curve, K K. The part of the pattern thus set out will give the side portion of the article, or we may imagine it to be the development of the part of large cone. The ends can now be added by opening the compasses to the slant height of small cone B S, as shown in the elevation, and marking it along the lines B L in the pattern, thus obtaining the centres, S S. The curves for the end part of pattern are now set out from these centres, using radii S B and S K. The outside curves, which are shown marked B F, are now cut off equal in length to the curve B F on the plan. This is best accomplished by bending a piece of wire along the curves, as before mentioned. Particular notice must be taken that the points F are joined to the centres S. There is no need to trouble about the length of curve for the bottom of pattern, as this will be cut off to the correct proportion by the radial lines as drawn. This may be tested by measuring the length of the curve, and seeing if it is equal to twice the length of the bottom quarter-oval.

### Position of Joints.

The pattern thus drawn out is, of course, for one-half of the oval vessel, two pieces off this being required to form the body of the article. It will be necessary to add laps as required for grooving, wiring, and knocking up.

It will be seen that the joints are at the end of the article, the reason for this being that that part having the sharpest curvature, it will be somewhat stiffer and stronger than the sides, hence the best position for placing the joint. Another reason that assists in determining the position of a wire joint is that, if possible, it should be covered with a lug, ear, or handle. In the present case, if the vessel is to be used as an oval tub or bath, the handles would be riveted over the end grooves, and thus materially assist to strengthen this part. Perhaps a further reason for fixing the grooves at the ends is that the pattern comes out much flatter when the joints are in this position than when on the sides; consequently the material will cut up to greater advantage. The economical cutting up of sheets and plates should always be taken into account when thinking of the position of joints. Also when stock sizes of sheets or plates are being used a little thought bestowed on the pattern will often save a large amount of waste in material.

When it is required to make the pattern for the body of an oval article in one piece, a little consideration of Fig. 139, will show how this can be done.

Before concluding it might be here pointed out that the lengths of both the radii used on the pattern can be calculated by the method shown, in connection with the cone, in Chapter XII.

Bodies of oval articles are usually shaped by bending in the rolls to the curvature of the ends, and then flattening out the side parts.

## CHAPTER XVIII.

## ARTICLES OF UNEQUAL OVERHANG.

MANY articles may be circular or partly circular in section, also having the property of their surfaces tapering to a point, and yet not be formed of a portion of a right cone (a cone whose axis is perpendicular to its base). Their patterns, however, can be readily developed when the surface is considered as a portion of an

## Oblique Cone.

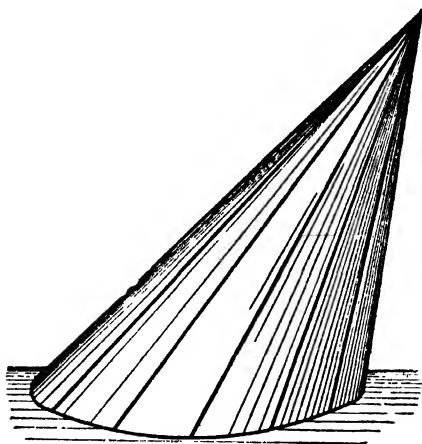


FIG. 140.

A cone of this description is one whose base is circular and whose axis is inclined to the base. Such a solid is shown in Fig. 140. Particular attention should be paid to the development of the surface of this kind of cone, as many articles can have their patterns readily set out for them when it is observed that they are formed from parts of the surfaces of oblique cones.

In marking out the pattern for an oblique cone, the principle involved is to imagine the circumference of the



base divided up into a number of equal arcs and the division points joined up to the apex of the cone, thus dividing its surface into a number of triangles. In Fig. 140 these lines are shown, the whole surface of the oblique cone being divided up into twelve triangles.

The setting out of the pattern for a complete cone is

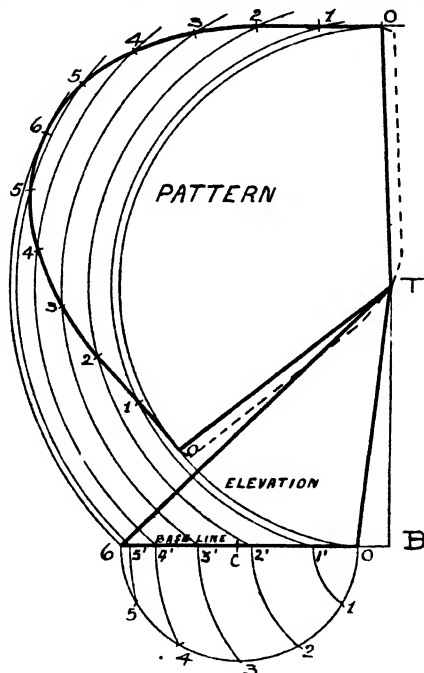


FIG. 141.

shown in Fig. 141. An elevation of the cone is drawn, and on its base a semicircle described and divided into six equal parts. The line TB is drawn perpendicular to the base line produced. Then with B as centre, and B 1, B 2, etc.

respectively as radii, the numbered points are swung round on to the base line as shown. Then using T as centre, and T O, T 1<sup>1</sup>, T 2<sup>1</sup>, etc., as radii, arcs of circles for the pattern are drawn around. The

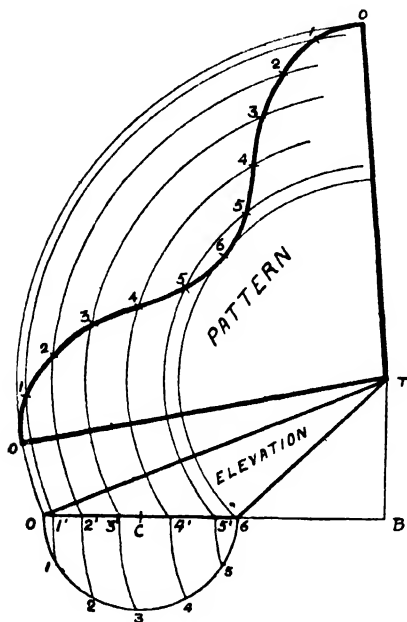


FIG. 142.

compasses are now set to a distance equal to one of the six parts into which the base semicircle has been divided, and commencing at some point on the inner arc, say O, the lengths are stepped from one arc to the other right up to 6, and then back over the arcs again to O. If the points O O are now joined up to T, and a fair curve drawn through the other points, the net pattern is complete. Allowances for the seam are shown by the dotted lines, the joint of same coming at the underside of the cone.

The pattern for a circular oblique cone which has a large amount of overhang is shown set out in Fig. 142. The distance that the top overhangs the centre of the bottom will be equal to CB, as in the last example. The height of the top above the base will, of course, equal BT. So that where these sizes are given, together with the diameter of base, the elevation of the cone will be drawn by first putting

in the lines T B, B C, and then marking off the base O 6. It will be observed that in this case the seam is arranged to come down the centre of the back of cone.

### Tapered Connecting Pipe.

The frustum of an oblique cone can very conveniently be used to join together two circular pipes of unequal diameter, whose centre lines are parallel, and whose ends are cut square. A connecting pipe of this description, together with the pattern development, is illustrated in Fig. 143.

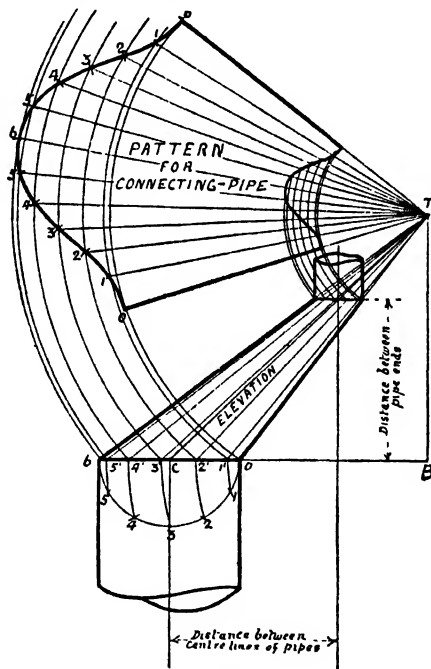


FIG. 143.

meter, whose centre lines are parallel, and whose ends are cut square. A connecting pipe of this description, together with the pattern development, is illustrated in Fig. 143.

The elevation is first drawn by setting in the centre lines, the distance between the pipe ends and the pipe diameters. To complete the oblique cone, of which the tapered pipe is a part, the back and throat lines are produced until they meet at T. To obtain the pattern the surface of the whole cone is developed as in the last two examples, and the portion of the top of cone cut away, as will be explained. After swinging the points 1, 2, 3, etc., on to the base, they are joined up to the top of cone, and where these lines cross the joint line at the top of connecting pipe, will determine the lengths of lines required to mark along to obtain the shape of cut at small end of pattern. In the figure all the lines are shown swung around on to the pattern lines. The points so obtained are joined up with an even curve, and thus the net pattern is finished. No allowances are shown in Fig. 143; but these can be put on to the sides and ends of pattern to suit the method of jointing adopted.

Before passing from this it should be pointed out that whilst the ends of the connecting pipe in the above case are circular, a section of the tapered pipe taken perpendicular to its centre line will be elliptical, and consequently when the overhang is great the pipe will be very flat, as in Fig. 142, and its area restricted. If it is required to have a tapered pipe of circular section, then the method shown in Chapter V. will have to be followed.

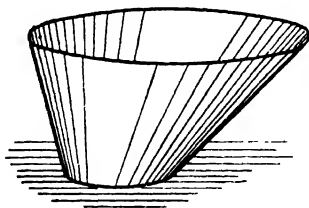


FIG. 144.

### Unequal Tapering Circular Article.

Any article whose top and bottom are circular, parallel, and of unequal overhang, such as Fig. 144, can have its

pattern developed as a frustum of an oblique cone. The pattern for such an article is shown set out in Fig. 145. Although the shapes seem somewhat different, the same method of construction for obtaining the pattern lines can be followed as in Fig. 143; the lines being denoted in exactly the same manner. No allowances for wiring or

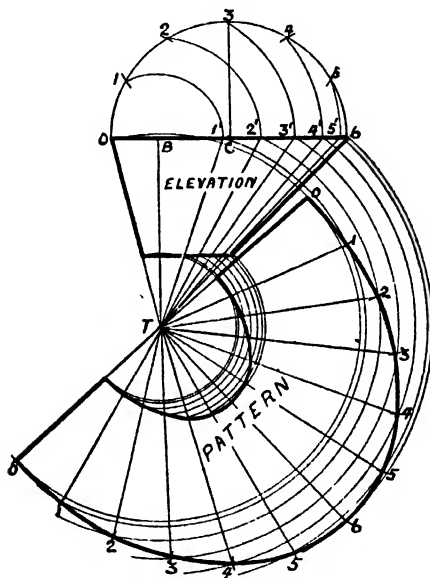


FIG. 145.

jointing have been added to the net pattern; but these can be put on as required.

### Tapering Y-Piece.

The oblique-cone method can be used for setting out the pattern for the connecting pipes in a tapering Y-piece, as

shown in Fig. 146. Here the problem resolves itself into jointing up two small pipes to one large one, the ends of the straight pipes all being square to their centre lines.

The setting out for the pattern is explained by Fig. 147. In practice there is no need to draw a complete elevation; all that is needed is the shape of a connecting pipe; but in the present case the full elevation is shown to better explain the way the form of a connecting pipe is obtained. To

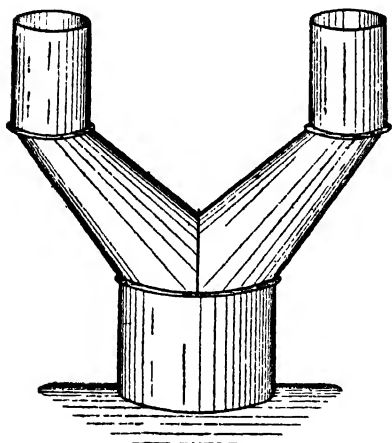


FIG. 146.

make the setting out plainer, definite dimensions in this case have been taken. The diameter of the main pipe is 17 in. and that of the branch pipes 8 in.; the distance between centre lines of branch and main pipes 10 in. and the distance between their ends 13 in. These dimensions are set out, as shown in Fig. 147, and to obtain the correct position of the joint line of the connecting pipes their

back lines are run down to the edges of the main pipe, as seen by the dotted lines, the point of intersection 6" giving the top end of the joint line. The pattern for the frustum is set out, as explained in connection with Fig. 143, the toe portion being afterwards cut away. To do this we must first get the lengths of lines required. Join B to 5, and where this line cuts line 3 C swing about B on to the base 0 6, and from this point project up and thus obtain point 5" in the elevation. In the same way find point 4". Then

with T as centre, swing these points on to their corresponding lines in the pattern. Join the new-found points with an even curve, add allowance for jointing as required, and the pattern is ready for use.

### Multiple-way Piece.

If it is desired to join more than two branch pipes on to the main pipe, then the above method will still hold good. The first thing to do is to obtain the plan of a joint line; thus in Fig. 147 the line 3 C on the semicircle, it will be readily seen, is the plan of the joint line when there are two branch pipes. To obtain the position of the plan of one of the joint lines when there are more branch pipes than two, a line will have to be drawn through C, making an angle with O C equal to—

$$\frac{180 \text{ degrees}}{\text{number of branch pipes}}$$

Thus, suppose there are three branch pipes, then the angle of the joint line will be—

$$\frac{180}{3} = 60 \text{ degrees.}$$

In this case the plan of the joint will be the line 2 C (Fig. 147). Now for the pattern. Where the line 2 C crosses the lines B 3, B 4, and B 5, swing on to the base line with B as centre. From the base line project up on to the correspondingly numbered lines in the elevation, thus obtaining the points 3°, 4°, and 5°. Now with T as centre swing these points around on to the pattern and draw in the curves. The thick dotted curve thus shows the cut for the toe of pattern when three branches are required to be jointed to one main pipe.

In the same way as above, after fixing the position of the joint-line plan, a pattern for a connecting pipe for any number of branches can be set out. On examining Fig. 146,

it will be seen that all the joints are paned down. They may, of course, be knocked up if the material is sufficiently unalleable to stand the operation. The allowances for this method of jointing will be a double edge on the end

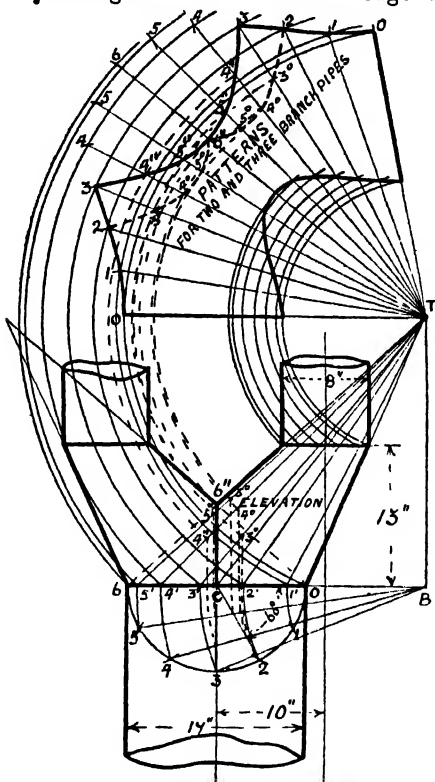


FIG. 147.

of each straight pipe, a single edge on the ends of each tapered pipe, and a double edge on one and a single edge on the other to form the middle joint of the connecting pipes.



## CHAPTER XIX.

## IRREGULAR TAPERING ARTICLES.

**Article with Round Top and Semicircular-ended  
Oblong Bottom.**

THIS is an article (Fig. 148) which belongs to the family of the oblique cone, for its rounded surface at the ends is formed of two half-frustums and its flat sides of two triangles.

Its pattern is shown struck out in Fig. 149. A quarter-plan and a half-elevation are marked out as seen, and the point B obtained by joining 3 to c, and producing to meet the base line. The points 1, 2, and 3

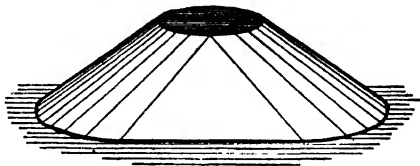


FIG. 148.

are swung around and joined up to T. The line T O on the pattern is made the same length as T O on the elevation. Arcs of circles are then drawn with radii T 1', T 2', and T 3', the points 1, 2, and 3, and the corresponding points for the inner curve up to C being obtained as in Fig. 143. Now take C on the pattern as centre and C 3 as radius, and mark the arc as shown, cutting off a point upon it by making line 3 3 equal in length to twice the line 3 4 from the plan. Thus we now have the two flat triangles added on to the first portion of the pattern. The two centres for the remaining lines can, of course, easily be fixed when it is remembered that their lengths are exactly the

same as the lines used in marking out the first part of the pattern.

Without the object is very small the body of the article will be made up in two pieces, the seams being at the ends

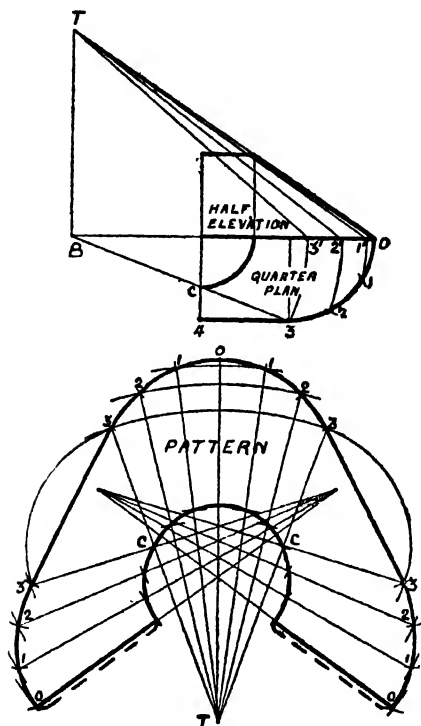


FIG. 149.

and coming along the lines through 0 on the pattern. The sheet and metal plate worker, however, should find no difficulty in making up an article in any number of pieces if he can strike out the pattern for the complete body.

# Article with Circular Top and Oblong Bottom with Rounded Corners.

The surfaces of many articles are what might be described as of a compound character—that is, they do not follow the surface shape of any one particular solid, but are built up of parts of surfaces of one or more solids, perhaps combined with one or several plain figures. One simple example of this has been shown in Fig. 148, and we shall now give two more typical cases of this class of pattern-marking.

In all cases it should be borne in mind that the first thing to do is to carefully analyse the surface so as to determine how it is formed. In Fig. 150 an article is shown whose top is circular, and whose bottom has straight sides, with corners formed of quarter-circles. On examination it will be seen that the rounded parts are each a quarter of a frustum of an oblique cone, and that the flat surfaces are triangles. In setting out the pattern (Fig. 151) a quarter-plan is first drawn, as shown, and the point B obtained by joining 1 to *a* and 4 to *c*, and producing the lines until they intersect. Through B a line is drawn parallel to *a o*, and the points 1, 2, 3, and 4 swung on to it, as in the previous cases.

these are then joined up to T. It, perhaps, should be here mentioned that the point T in this example is found by produc-



FIG. 150.

ing the back line  $o^1 a^1$  until it intersects the perpendicular drawn up through B. In marking out the pattern the line 0 A is made equal in length to  $a^1 o^1$  on the elevation. A line is drawn square to it through 0, and cut off on each side equal to 0 1 in the plan. The line 1 A is produced, and the point T determined by making 1 T equal in length to

T 1<sup>1</sup> from the elevation. The points 2, 3, and 4 on the pattern, and also those for the curve A C, are now obtained as in the other cases of the oblique cone. C is now taken as centre and C 4 as radius, and the arc drawn as shown, the next point 4 being fixed by making line 4 4 equal to twice the length of *d* 4 in the plan. The other points will be found, as previously explained, in connection with Fig. 149, each quarter of the pattern being the same shape. If

the article is made up in two or more pieces, it will be an easy matter to mark out the portion of pattern required.

### Hood with Round Top and Flat Back

A pattern for a hood whose top is circular and bottom rectangular with two square and two round corners (Fig. 152) can be obtained on the same principle as in the previous articles. An inspection of the hood surface in the sketch will lead us to see that it is built up by two quarter-frustums of an oblique cone and

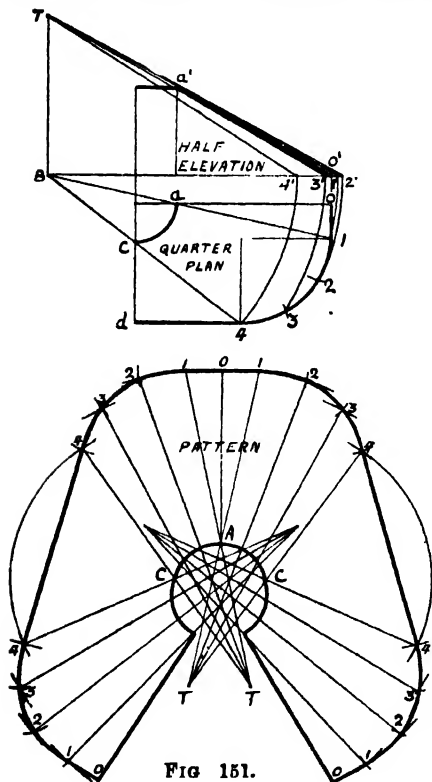


FIG 151.

a flat triangle for the front, a flat triangle and a quarter-frustum of an oblique cone for each side, together with a flat triangle for the back.

To get the length of the pattern lines, a half-plan and a half-elevation are set out (Fig. 153), the point B and the true lengths of lines being obtained as in the last example. The setting out of the pattern up to the lines C 2 will be

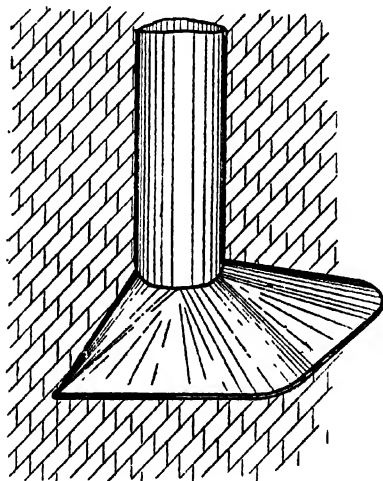


FIG. 152.

exactly as in Fig. 151. Before proceeding any further with the pattern, the lengths of lines required for the remaining portion will have to be determined. To do this, set along distances  $1^1 c^1$ ,  $1^1 d^1$ , and  $1^1 O^1$  in the elevation respectively equal to  $1 c$ ,  $1 d$ , and  $1 O$  in the plan, and join

up to  $a^1$ . On the pattern, the line 2 1 is equal in length to the line with the same figures in the plan; and the lines C 1, D 1, O<sup>1</sup> 1 are respectively equal to lines  $c^1 a^1$ ,  $d^1 a^1$ ,

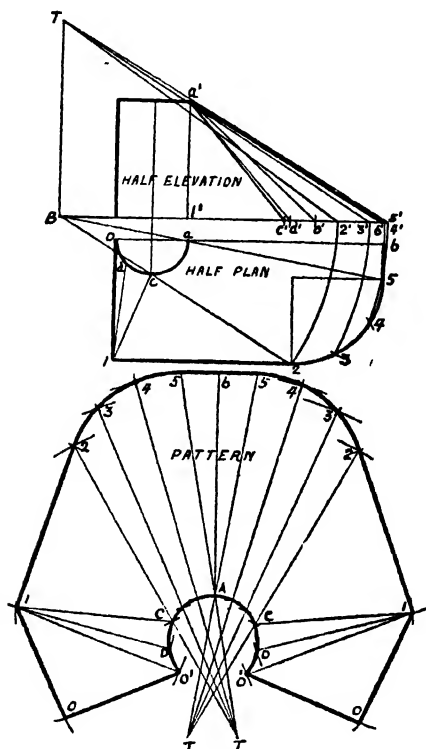


FIG. 153.

and O<sup>1</sup>  $a^1$  in the elevation. The distance between C and D and D and O<sup>1</sup> on the pattern will, of course, be equal to the lengths of the arcs  $c d$  and  $d 0$  on the plan. To form the

last triangles of the pattern, the lines  $O^1 O$  will be made equal in length to the back line in the elevation, or the line  $1^1 a^1$  and the line  $1 O$  equal to the line with the same figures in the plan.

It is perhaps as well to point out that the patterns for all the objects mentioned can be struck out by the method of "triangulation." But whilst this method is general in its application, it is not so convenient for the particular cases as those shown.

### Article with Round Top and Oval Bottom.

A vessel of uneven taper having a circular top and an oval bottom can have the pattern for its body set out in a similar manner to that of several of the objects previously dealt with. Examination of Fig. 154 will show that its surface is formed of parts of two different sized and shaped oblique cones. The points  $T T$  show the tops of the oblique cones that are used for the end parts of the article, and the point  $t$  the apex of one of the oblique cones used for obtaining the side parts of the body surface.

A quarter-plan and two half-elevations of the vessel are first set out as shown in Fig. 155, the quarter-oval being marked out as explained in Chapter XVII. The points  $Q$  and  $P$  show the centres for the end and side curves of the oval, and point  $3$  where the two curves meet. Having constructed the quarter-oval, divide each of the two curves into, say, three equal parts. Draw the line  $c a$  parallel to  $Q 3$ , then joining  $3$  to  $a$  and producing to meet the centre line in  $B$ . Run along a line from  $B$  square to the centre line, and where this intersects the end line  $o e$  produced in  $T$ , will give the apex of the oblique cone which forms the end part of the article. The apex of the oblique cone, which forms the side part, can be determined by running up a

perpendicular to the base line through *b*, and producing line *6 d* to meet it in *t*. With *b* as centre and *b 5*, *b 4*, *b 3*, respectively, as radii, swing around on to the base line, thus obtaining points *3'*, *4'*, and *5'*. In the same way, taking *B* as centre, swing points *3*, *2*, and *1* on to the centre line, giving points *3''*, *2'*, and *1'*.

To mark out the pattern, set down the line *6 t* equal in length to the line *6 t* in the elevation. Then, using *t* on the pattern as centre and radii *t 5'*, *t 4'*, and *t 3'*, draw

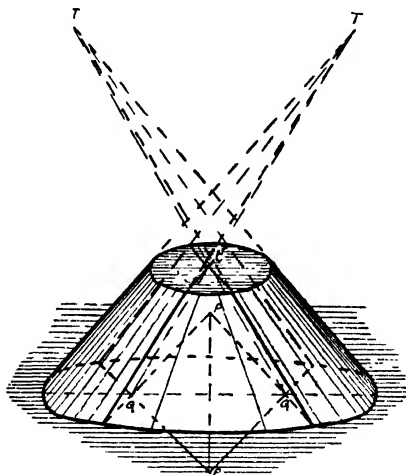


FIG. 154.

arcs of circles as shown. Now set the compasses to the length of one of the three arcs on the side oval, say, *5 6*, and commencing at point *6* on the pattern, step from one arc to the other, marking points *5*, *4*, and *3*. Join the points up to *t*, and produce *3 t* to *T*, making *3 T* equal in length to the line *3'' T* in the side elevation. Then, using *T*



as centre and radii  $T 2'$ ,  $T 1'$ , and  $T 0$ , from the elevation, describe arcs as seen. Now fix the compasses to the length of one of the arcs on the end of quarter-oval, say,  $0 1$ , and commencing at point 3 on the pattern, step off points 2, 1, and 0, joining these up to  $T$ .

To obtain the necessary points for the inside curve of pattern, set the distances along from  $t$  and  $T$  respectively, as measured along the corresponding lines from  $t$  and  $T$  in the elevations down to the top line of the article—that is, the lines  $t D$ ,  $T A$ , and  $T E$  on the pattern will be respectively equal to lines  $t d$ ,  $T a'$ , and  $T e$  on the elevations, and so with the other points.

The pattern is set out for one-half of

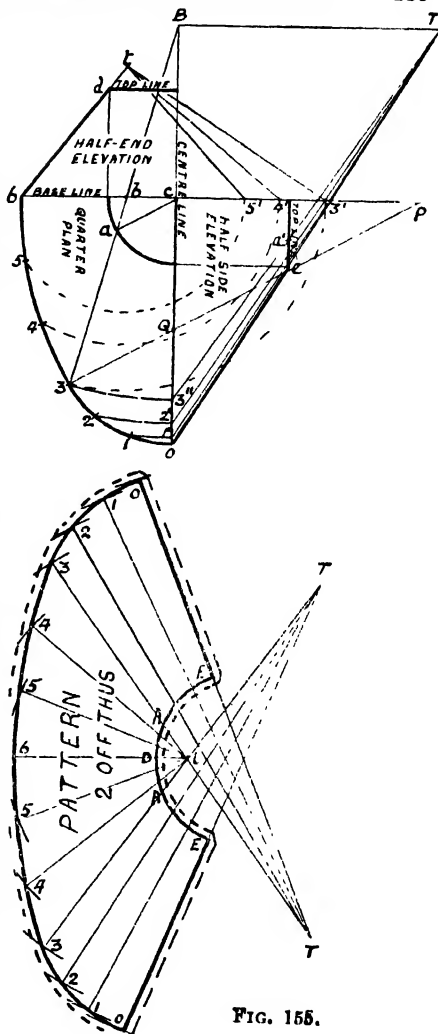


FIG. 155.

the body only, the joints coming down the middle of the ends. Imagining that the article is turned upside down, the allowances are put on for wiring around the top edge, knocking up a bottom, and for a grooved or riveted seam.

### Irregular Tapering Article with Oblong Semicircular-ended Bottom and Round Top.

In addition to those dealt with in the last chapter, there are a number of hoods, hoppers, or body parts that are formed in a somewhat different manner. Thus Fig. 156 represents an article whose top is circular and bottom oblong with semicircular ends; but in this case the centre of the top is vertically over the centre of one of the semicircular ends. On examination it will be seen that the left-hand part of surface is formed of half of a frustum of a

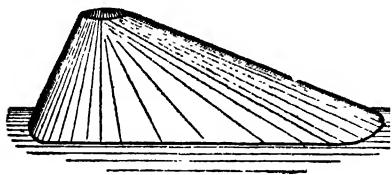


FIG. 156.

right cone and the right-hand part of half of a frustum of oblique cone, the side parts being flat triangles. Perhaps the building up of the surface will be better understood on referring to Fig. 157, where the half-pan is shown

To obtain the lengths of the pattern lines, the apex *T* (Fig. 157) of the oblique cone is obtained by joining 4 to *a* and producing the line to *B*, then running up a perpendicular to meet the line 7 *d* produced to *T*. The apex *c* of the right cone is found by producing the slant side to meet the centre line. Taking *B* as centre, the points 4, 5, and 6 are swung on to the base line, and then joined up to *T*.

To mark out the pattern, the first line set down is T 7, this being of the same length as the similarly-numbered line in the elevation. Then taking T as centre and radii respectively equal to T 6', T 5', and T 4' in the elevation, the three arcs are drawn. The compasses are now set to the length of one of the arcs in plan, say 4 to 5, and commencing at point 7 on the pattern, the points 6, 5, and 4 are struck off. The points on the inner curve of pattern to form top of article will be found by marking the distances along the lines from T, equal to the lengths of lines measured from T in the elevation down to where they cross the top line. Thus, T D on the pattern is equal to T d in the elevation, and so on for the remaining points. The compasses are now set to the length of line 3 4 in the plan, and with 4 on the pattern as centre, arcs are drawn, these being cut by making A 3 equal to the slant length o e in the elevation. The line 3 A is now produced, and A C set off equal in length to e c in the elevation. The point

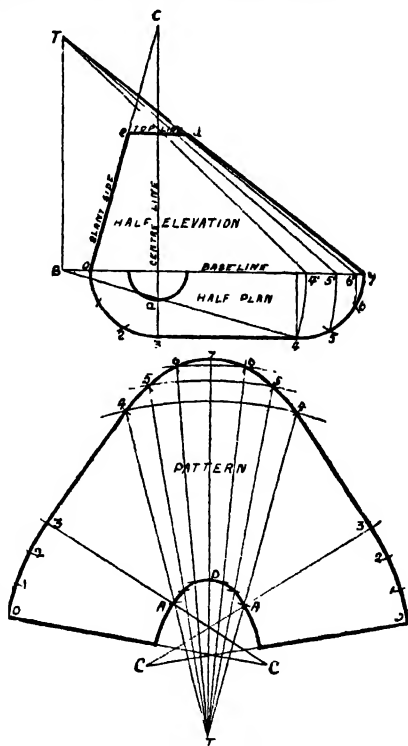


FIG. 157.

Thus, T D on the pattern is equal to T d in the elevation, and so on for the remaining points. The compasses are now set to the length of line 3 4 in the plan, and with 4 on the pattern as centre, arcs are drawn, these being cut by making A 3 equal to the slant length o e in the elevation. The line 3 A is now produced, and A C set off equal in length to e c in the elevation. The point

C is now used as a centre, and the part 3 to *o* struck out in the usual way for a right cone development.

In laying out patterns for articles of this description, it should be noticed that the straight line and curved parts

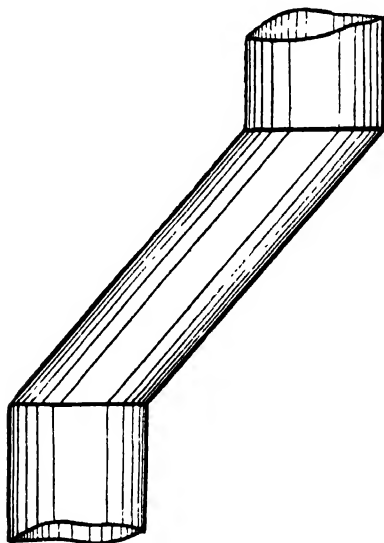


FIG. 158.

run into each other without break or unevenness. It is also as well to check the setting-out by testing if lines 3 A and 3 4 (Fig. 157) are square to each other, as they should be if the pattern be marked out correctly. For a large hood or hopper the body can be made up in as many pieces as will be suitable to the size of sheets or plates used.

## CHAPTER XX.

### ARTICLES OF OBLIQUE CYLINDRICAL SHAPE.

#### Oblique Cylinder.

THE shapes of some unequal tapering articles may be made up wholly or partly of the surface, or some portion of the surface, of an oblique cylinder; by which is meant a pipe whose ends are circular and inclined to its centre line. Such a cylinder is shown as an

#### Oblique Connecting Pipe.

in Fig. 158. It should be remembered, in dealing with this, that although the ends of the oblique pipe are circular, a cross-section of the pipe will be elliptical in shape; hence the more inclined the pipe becomes the flatter it will be, and the smaller its passage area. For this kind of connecting pipe it will be observed (Fig. 158) that the straight pipes are the same size, and also that their ends are cut square.

We shall first set out the pattern for a pipe of this description, and afterwards give a couple of examples illustrating its application to irregular tapering objects.

The elevation of the connecting pipe only is shown in Fig. 159, that being all that is necessary to obtain the development. A semicircle is described on one end of the pipe as in the figure, this being divided up into, say, six equal parts, and perpendiculars drawn to the end line 0 6,

as seen. Through each of the last found points lines are run along parallel to the centre line of the pipe. Now to sweep out the pattern. Run lines down through points, 0, 1', 2', etc., square to the pipe, and then carefully setting the compasses at a distance equal to the length of one of the six parts of the semicircle, step distances 0 to 1, 1 to 2, etc., from one line to the other on the pattern. The curve on the pattern for the other end of the pipe can be set out in the same way, or lines run down and points from the first curve projected across. The better plan in the workshop is to mark one curve out carefully (or one quarter of it will do, as shown by the shaded part in Fig. 159), cut out in sheet metal, and use this as a tem-

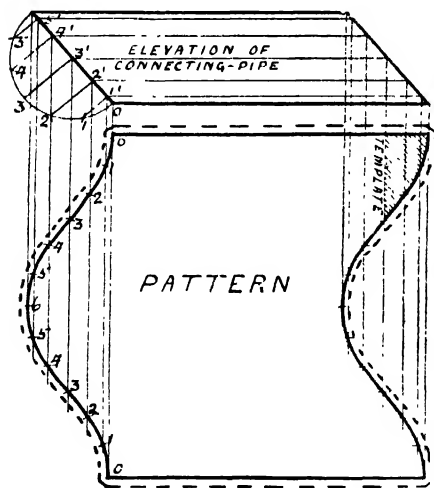


FIG. 159.

plate for the other end. The pattern, too, should be set out quite distinct from the elevation, as methods of projection are useless in workshop practice, and are only used in this descriptive way to better explain the connection between the elevation and the pattern. Allowances for jointing are put on as shown by the dotted lines.

**M**ultiple-way pieces having portions of an oblique cylinder for the branch pipe connecting tubes can be set out in a somewhat similar manner to those shown in the last chapter.

### Funnel with Central Circular Top and Oblong Semi-circular-ended Bottom.

In this particular example (Fig. 160) it should be noted that the diameter of the top and the width of the bottom are equal; hence its curved surface is formed of two upper halves of an oblique cylinder, together with two upright triangles for its flat sides.

The development of the surface to form the pattern will be followed by referring to Fig. 161. A half-elevation is drawn, and a quarter-circle described on the base, the radius of this, of course, being equal to the half-width of funnel. The quarter-circle is then divided into three equal parts, and lines through each part run square up to the base line. Through the points on the base lines are now drawn parallel to the slant end line. Make  $a$   $0'$  square to  $t$   $a$ , and then set up distances  $a$   $3'$ ,  $b$   $2'$ , etc., equal to the corresponding lines  $a$   $3$ ,  $b$   $2$ , etc., on the quarter-circle. Join  $0'$  to  $3'$  with an even curve. This will be a quarter of an ellipse, and will give the half-girth of rounded ends.

To mark out the pattern draw in a centre line as shown (Fig. 162), and a girth line square to it. For the length of the girth line, set along distances equal to the lengths of the separate parts of the girth-curve in elevation, the points being numbered in the same manner. Draw lines square to the girth line through each point, and then mark off distances  $2' 2$  equal to  $b' b$ ,  $1' 1$  equal to  $c' c$ , and  $0' 0$  equal

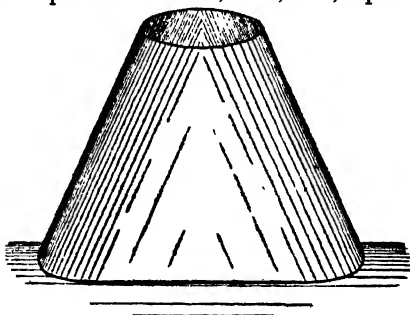


FIG. 160.

to  $O' O$  taken from the elevation. The parallel lines on the pattern will now be cut off at the same length, that is to equal  $a t$  from the elevation. The triangle  $3' T 3'$  can be easily constructed, for the line  $3' 3'$  will, of course, be equal to twice the length of line  $a d$ . The setting out of the end parts of pattern will be nothing more or less than a repetition of the construction followed for the middle portion. For the pattern to be accurate it should be noticed that its curves run into the straight lines without lump or hollow. On examination it will be seen that all the curves are exactly the same shape, and in practice the pattern would be marked out by making a small template (like the shaded part of the end), and marking all the curves at top and bottom from this.

The above method of laying out the pattern has been purposely arranged somewhat different to that shown in Fig. 159, but either method can be applied in both cases, the choices depending upon the size and shape of articles.

### Shoe-Shaped Funnel or Hopper.

A funnel may require to be of the shape shown in Fig. 163, which, on inspection, will be seen that its surface is composed of half an oblique cylinder for the front, two right-angled triangles for the sides, and half of a right cylinder (a round pipe whose ends are square to the centre line) for the back.

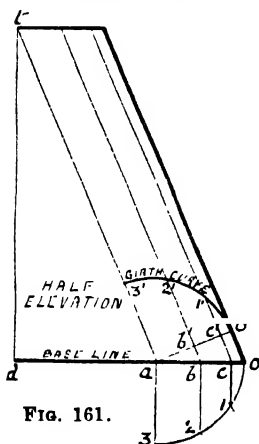


FIG. 161.

The striking out of the pattern is illustrated by Fig. 164. An elevation is drawn, and a semicircle described on the base, this being divided into six equal parts, and numbered as in the figure. Perpendiculars are run up from points





The pattern is obtained by drawing in a centre line 6 6, and marking it off equal in length to 6 *t* from the elevation. Then the distances 6" 5", 5" 4", and 4" 3' are measured from the elevation and stepped along the centre line of pattern, as indicated. Through these points lines are drawn square to the centre line. Now set the compasses to

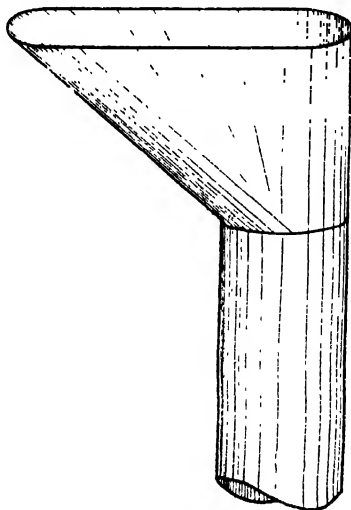


FIG 163.

the length of one of the small arcs, say, 3 to 4, on the semi-circle, and commencing at point 6 on the pattern, mark off points 5, 4, and 3 by stepping from one line to the other, as seen. The right-angled triangle A B 3 is now marked out by making A B equal *a b* and 3 B equal to 3' *b* from the elevation. The last portion of the pattern on each end is for the straight pipe part, and this will, of course, be equal in length to the quarter-circle 3 to O.

Allowance for wiring, grooving, or other form of jointing can be added to the pattern as required.

The typical examples shown in this and the last chapter will, it is hoped, illustrate what has been said about articles whose surfaces are compounded of the surfaces of two or

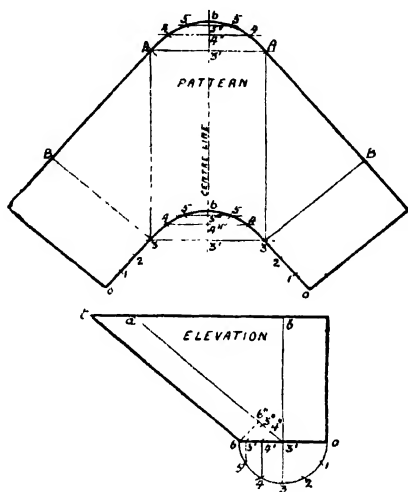


FIG. 164.

more solids. In Chapter XXV. such objects as tall-boy chimney-pots and ventilator bases are dealt with.

## CHAPTER XXI.

## ELLIPTICAL WORK.

THERE are many objects of elliptical shape that require to be made up out of sheet and plate metal. It is, therefore, essential that workmen in these trades should know one or two practical methods for describing ellipses. Whilst there are a great number of different ways in which an ellipse may be set out, there are only two that are of much use for workshop purposes. We shall now proceed to describe these two methods.

## Construction of Ellipse.

One way of describing the ellipse is that known as the "string method," and is illustrated by Fig. 165. The diameters *A B* and *C D* are first set out at right angles, as there shown, and the points *F'*, *F* (called the foci) obtained by setting the compasses at half the long diameter and using *C* or *D* as centre, and cutting *A B* in *F'*, *F*. A pin or nail is now stuck in each of the points *A* and *F*, and a piece of string brought round the two nails, as shown, and tied. The nail is then drawn out of *A* and fixed in *F'*, as seen in the lower figure. The string is stretched tight by holding a scriber or pencil, as at *P*, and at the same time the ellipse described by moving the pencil all round, as shown. To get an accurate result, string that has very little stretch should be used.

If it is desired to mark an ellipse on a plate or sheet, where there will be difficulty in fixing the pins, a good plan is to clamp a batten on to the plate and drive the pins into this.

There is an important property of the ellipse which is worth while remembering, and that is: "The sum of the

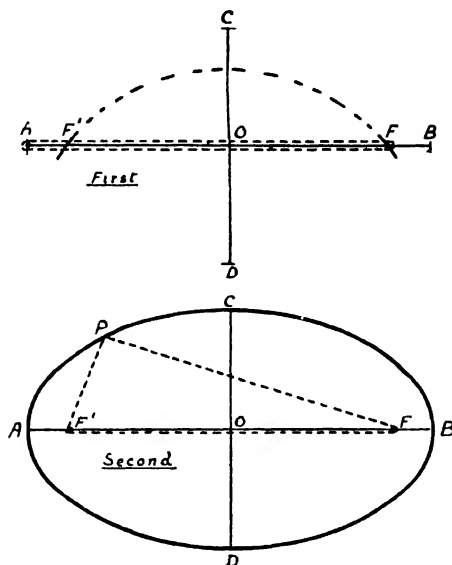


FIG. 165.

distances of the foci from any point on the ellipse is a constant quantity, and is equal to the long diameter." It is, indeed, from this property that we are enabled to construct the ellipse by the string method; for if the lengths  $PF'$ ,  $PF$  be added together, they will, for any position of  $P$ , be equal to  $AB$ . Knowing this peculiarity of the ellipse, the ingenious reader should be enabled to devise one or two other simple methods for its construction.

The string method is most adaptable for large ellipses, and for smaller ones what is known as the "trammel method" is most suitable. This latter will now be explained.

A trammel (Fig. 166) need be nothing more than a strip of cardboard, wood, or sheet metal. Half the long diameter,  $PE$ , and half the short diameter,  $PF$ , of the ellipse must first be set along from the end of the trammel. And then to construct the ellipse, two lines at right angles are

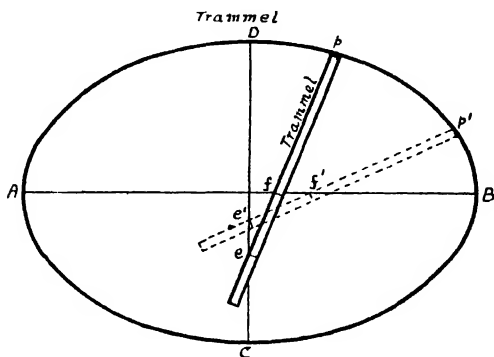


FIG. 166.

drawn, and on these the trammel placed, the points  $e /$  being respectively on the lines  $DC$  and  $AB$ . The trammel is now moved into different positions, points on the ellipse being obtained by marking the end  $P$ . When a sufficient number of points are obtained they can be connected with an even curve, and so the whole ellipse described. The important thing to notice is that the point  $e$  must always slide on the line  $DC$  at the same time as point  $f$  is moving along line  $AB$ . Two positions of the trammel are shown on Fig. 166.

It is not a difficult matter to make a trammel with two adjustable pegs and wood or metal cross-shaped slides (to lie along the ellipse diameters), and with this simple apparatus

construct ellipses in a similar manner to that in which circles are described by compasses.

### Circumference of Ellipse.

The circumference of an ellipse can be found by adding together the semi-diameters and multiplying by  $3\frac{1}{7}$ . Thus in Fig. 165, suppose A B = 24 in. and C D = 18 in.; then the circumference equals—

$$(12 + 9) \times 3\frac{1}{7} = \frac{21 \times 22}{7} = 66 \text{ in.}$$

The rule, as given, is only approximately correct, but is good enough for workshop practice when the ellipse is not very flat. Calculated by a rule giving more accurate results, the circumference should be about  $\frac{3}{8}$  in. longer than above. Unfortunately, however, very accurate results are difficult in manipulation. In practice, the simplest way of obtaining the length of the circumference is to bend a thin wire along a quarter of the ellipse, as set out, and multiply this length by 4.

### Area of Ellipse.

The area of an ellipse can be calculated by multiplying the semi-diameters together, and this product by  $3\frac{1}{7}$ . Thus, for an ellipse having diameters 24 in. and 18 in. the area equals—

$$12 \times 9 \times 3\frac{1}{7} = \frac{12 \times 9 \times 22}{7} = 339\frac{1}{7} \text{ sq. in.}$$

By applying the above calculations to what has been stated in Chapter XII., the cubic contents, or number of gallons, that an elliptically conical vessel will hold can be obtained.

### Elliptical Cone or Cap.

Just as we may have a circular cone, either right or

oblique, so in the same way we may have an elliptical cone. A sketch of a cone whose base is an ellipse, and whose axis is perpendicular, is shown in Fig. 167. A cap may be of this shape, or an object may be formed by some part of an elliptical cone surface. We shall now give a few examples of pattern-marking for this class of work.

In Fig. 168 the method employed to set out the pattern for a complete and also for a frustum of an elliptical cone is shown. A half-elevation of the cone  $c O t$  is drawn, and also a quarter of the base ellipse. This latter is

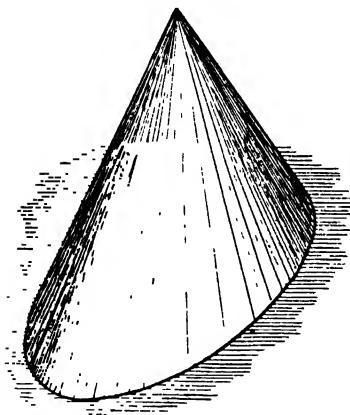


FIG. 167.

divided into four equal parts, and taking  $c$  as centre, the points 1, 2, etc., are swung on to the base line  $c O$ . The points  $1' 2'$ , etc., are then joined to the apex  $t$ . To mark the pattern out the compasses are set respectively to  $t O, t 1', t 2'$ , etc., and the arcs of circles, as shown, described from the point  $T$ . Then, fixing the compasses to the length of one of the parts on the quarter-ellipse, and commencing at 4 on the pattern, the points 3, 2, 1, and 0 are stepped from one arc to the other, the points

then being joined to form an even curve. To form a complete cone, two parts like  $O T O$  would have to be cut out.

For an article made up like the shape of a frustum of a cone, the inner portion of the cone pattern would have to be cut away. Thus, suppose  $a b$  represents the half top of the article, then the lengths of lines from  $t$  down to where they cross  $a b$  will give the lengths of lines to mark the



points to form the curve B D B. Thus, T B equals  $t b$ , and T D equals  $t d$ , and so on for the other lines.

It should be noted in setting out the shapes of tapered elliptical articles that only three dimensions for top and bottom can be worked to. In the present case we have the length and breadth of the bottom and the length of the top only. If required for shaping, or other purposes, the width of the top can be measured from  $a d$ , the length of this line giving half the width of the top. It should also be remembered that articles of the above description are not equal tapering, the ends having a greater overhang than the sides.

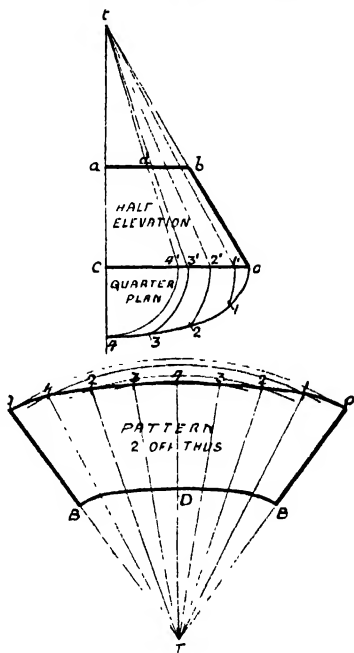


FIG 168.

### Elliptical Coal-Bucket.

There are many different kinds of elliptical coal-buckets, one of the commonest being that known as a "Waterloo," a sketch of which is shown in Fig. 169. To set the pattern out for the body of this is generally considered a somewhat difficult task. With careful consideration, however, and some understanding of the principles of development, the reader should find the difficulties disappear.

In the example as set out in Fig. 170 it is assumed that the back and the front of the bucket have the same taper:

hence the body will come out as a portion of an elliptical cone. The elevation is drawn as shown, and the end lines produced to meet in T. The centre line T t is drawn square to 6 0, and produced to 3'. The semi-ellipse is described and divided into six equal parts, perpendiculars being dropped from each division point on to 6 0. Through the feet of these perpendiculars lines are drawn from T and produced to the top curve of the elevation, thus obtaining

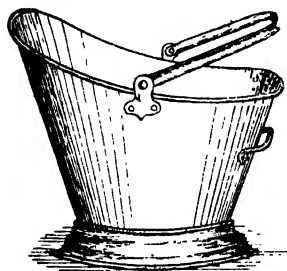


FIG. 169.

the points 1', 2', 3', etc. The points 1, 2, 3, etc., on the semi-ellipse are then swung about t on to the line 6 0, these latter points being joined to T, and the lines produced upwards to meet the horizontals drawn through the points on the top curve of the elevation. Thus, 5'' is obtained by connecting T to 5° and producing to meet the horizontal line drawn through 5'. In the same way the other

points 1'', 2'', etc., are fixed.

Now for the pattern. The curve 0 0 (Fig. 170) is obtained in exactly the same way as that on Fig. 168, the length of lines A 0, A 1, etc., being measured from T up to the base line 6 0. Thus A 5 equals T 5°, and so for other corresponding lines. The pattern construction lines are then drawn from A through each point and produced outwards. These radial lines are cut off to their proper lengths by taking corresponding lengths from the elevation. Thus A a = T 0'', A b = T 1'', A c = T 2'', and so for the rest of the points.

Allowance for wiring is added to the top end of pattern, for throwing off and knocking up on the bottom, and grooving on the sides.

The pattern for the foot is laid out exactly as in Fig. 168, the point *c* on the elevation (Fig. 170) representing the apex of the elliptical cone. For the inner curve, the lengths are measured from *c* down to the line 6 0, and for the outer curve down to the bottom line. Thus, C 5 and C *h* on the pattern are respectively the same length as *c* 5° and *c* *h* on the elevation.

Allowance is made for wiring on the outer part, a single edge on the inner, and for grooving or riveting on the ends. Details of the methods of attaching the bottom and foot to body are also shown on Fig. 170. If made of black sheet iron the bottom edge is annealed by running around in the fire, after which it is (1st) carefully thrown off by stretching, and

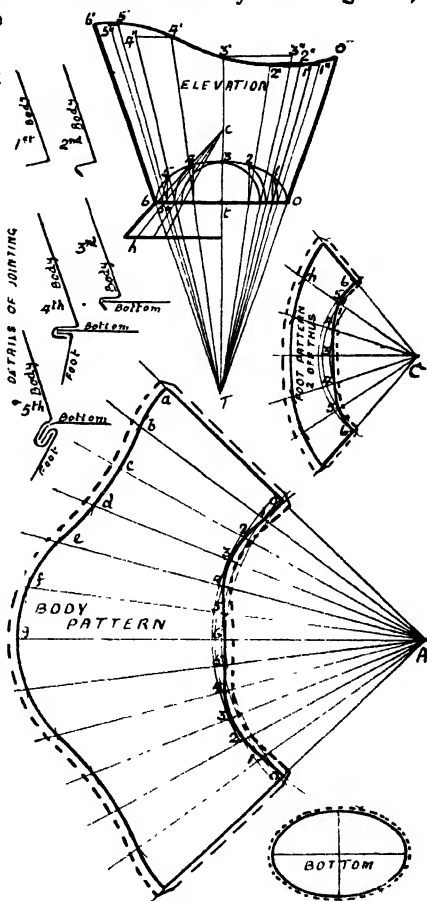


FIG. 170.

annealed again. The flange is then levelled with a mallet and (2nd) edged over. The bottom (3rd) is slipped in, and

after a single edge has been turned on the foot this, also, is put in and (4th) paned down, the latter operation being best performed on a bick-iron and then run around on a hatchet-stake. The final operation (5th) is the doubling-over, or knocking up, as shown in Fig. 171. A special knocking-up hammer is used, and the bench-stake being either a head, as shown, the back end of a side-stake, or the end of a bench-bar.

Whilst the illustration (Fig. 171) shows the knocking-up

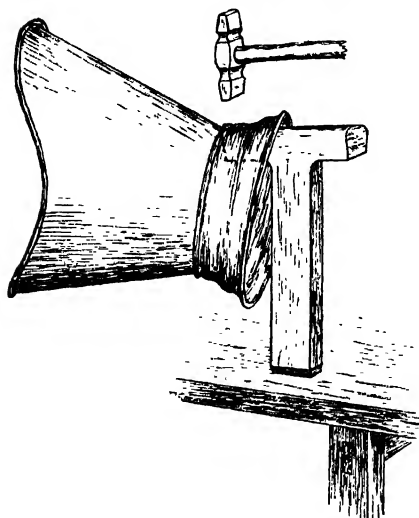


FIG. 171.

process on a coal-bucket, this method of attachment, it may be pointed out, is very commonly applied to a large number of sheet-metal articles.

### Oblique Elliptical Cone.

An article may take the shape of a portion of an elliptical cone of the above description—that is, one whose centre line is not square to the base.

The setting out of the pattern for an object of this character

can be done in a similar manner to that shown in connection with the oblique cone (Chapter XVIII.). A side-elevation is first drawn (Fig. 172) and the half-plan of the top. The line  $T t$  is drawn up square to  $O 6$  produced, and then with  $t$  as centre and  $t 1$ ,  $t 2$ , etc., as radii, the points are turned down on to  $O 6$ , giving the points  $1'$ ,  $2'$ ,

etc. These latter points are then joined to T. Now, using T as centre and T O, T 1', as radii, the arcs of circles are swept out. The compasses are next fixed to the length of one of the six parts of the semi-ellipse, and, commencing at O on the pattern, the points 1, 2, 3, etc., are stepped from arc to arc. The inner curve is obtained by drawing the radial lines on the pattern and cutting these by the arcs run around from the points where the corresponding lines intersect the bottom line *a d*.

The ends of the frustum will, of course, be similar in shape, and if it is desired to obtain the width of the ellipse at the bottom, this can be done by drawing *c b'* square to T *c*, and making *c b'* equal to *c 3*, joining *b'* to T, and then drawing *c' b''* square to T *c*; then *c' b''* will be the half width of the ellipse at the bottom of the frustum.

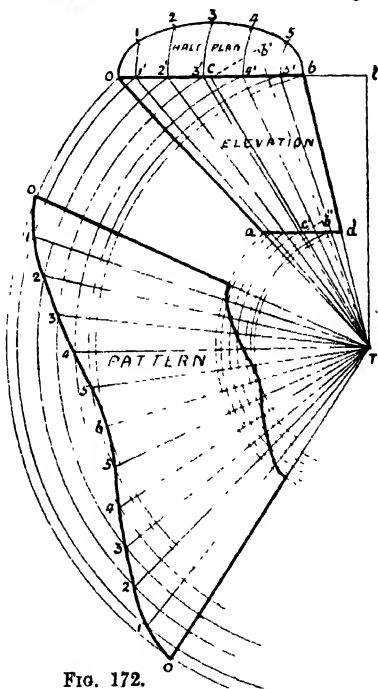


FIG. 172.

### Overhanging Coal-Bucket.

A coal-bucket whose body can be set out on the assumption that it is part of an oblique elliptical cone is shown in the elevation (Fig. 173).

The back and front are produced to meet in T, and a perpendicular, T *t*, run up to meet the line O 6. Using *t* as centre, the points on the semi-ellipse are swung down on to the line O 6, and the lines T 1', T 1'', T 2', T 2'', etc., drawn as in Fig. 170. The pattern is then set out as before explained.

### Elliptical Round Coal-Vase.

A coal-vase sometimes follows the shape shown in Fig.

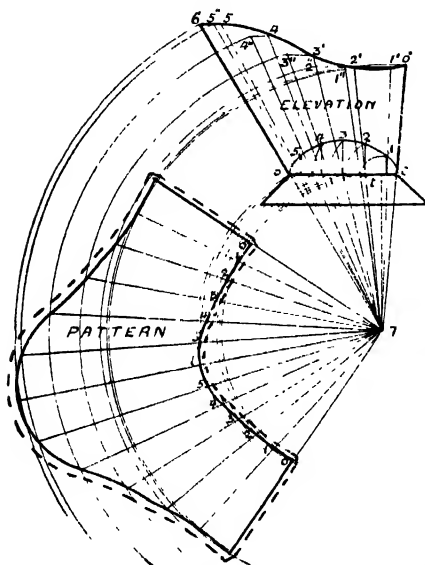


FIG 173.

174, the top being elliptical and the bottom round. If the top were made oval instead of elliptical, the pattern might be set out by one of the methods shown in Chapter XIX.

In this case, however, the method of triangulation will have to be used. It will at the same time further explain its application to articles of this description that are irregular in shape.

An elevation and a quarter plan are drawn as shown, the quarter ellipse and

quarter circle each being divided into three equal parts. The points on the plan are connected up, the lines thus representing the plans of the six triangles that make up a quarter of the complete body surface. To set out the

pattern we shall require to get the true lengths of all the lines shown in plan. The first line of the pattern to set down should be 3 D, this being made equal in length to 3'  $d$  in the elevation. To obtain the true length of the required second line (3 C), set 3  $c$  along the base lines from 3, thus marking the point  $c'$ ; then 3'  $c'$  will give the length of 3 C. The small arc through C will be drawn by using point 3 as centre and the length 3'  $c''$  as radius. The compasses are now set to the length of one of the arcs on the quarter circles, and with D as centre the point C is cut. The line 2  $c$  is now set along the base line from 2', thus fixing  $c''$ , this latter point being joined to 2". The line 2"  $c''$  gives the length of 2 C on the pattern. As before, an arc is now described shown passing through 2, using 2"  $c''$  as radius and C as centre, this being cut by using 3 as centre and the length of one of the parts

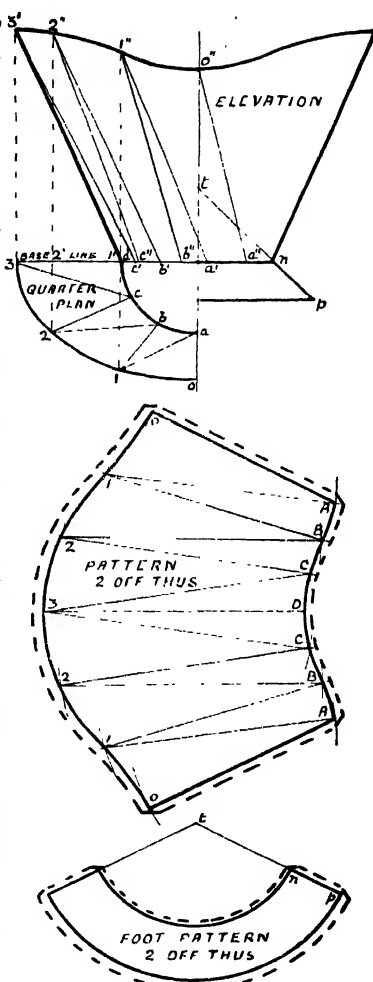


FIG. 174.

on the quarter ellipse as radius. Thus point 2 on the pattern is determined. The point  $b'$  is fixed by making  $2' b'$  equal to  $2 b$ , then  $2'' b'$  will give the length of  $2 B$  for the pattern. The length  $1' b''$  is made equal to  $1 b$ , line  $1'' b''$  then giving the length of  $1 B$ . The line  $1' a'$  is marked along equal to  $1 a$ , thus giving  $1'' a'$  the length required for  $1 A$ . And then the finishing line  $O A$  is obtained by setting  $O a$  along the base line from the foot of the centre line to give  $a''$ , and measuring off  $O'' a''$ . In this way the twelve triangles that build up the half pattern are set out. The points are joined up, and allowances put on as before.

The foot being a frustum of a right circular cone, the pattern will be marked by making the radii  $t n$  and  $t p$  on the pattern the same length as the letters denote in the elevation.

The methods of jointing can be the same as before, or the bottom can be knocked up on to the body, and the foot slipped over and riveted.

Before passing from the above example in the use of the method of triangulation, it is perhaps as well to point out that the true lengths of lines can be obtained by drawing a pair of lines at right angles, and setting along these the respective distances from plan and elevation; those from the plan being measured along the horizontal, and those from the elevation up the vertical, the slant lines then giving the true lengths for the pattern.



## CHAPTER XXII.

## ROOFING WORK.

## Galvanised Sheets and Gutter Angles.

GALVANISED corrugated sheet iron has an extensive application in roofing work. It is comparatively cheap, and when properly galvanised fairly durable. There is much dispute as to the length of time it will last. No definite "life," however, can be assigned to a galvanised iron roof, except all the conditions are fully known, and these are most difficult to determine, the length of time it will last depending upon the quality of iron and galvanising, thickness of sheet, and the kind of atmosphere the roof is placed in. In the sulphurous atmosphere of a manufacturing town it is probable that galvanised iron will not last more than one-quarter the time that it will in a pure country air. And, again, it will last longer in a dry atmosphere than in a moist one.

Galvanised iron is iron coated with zinc, and this latter metal has the distinct advantage of forming an oxide on its surface that is not dissolved by ordinary rainwater. If the water, however, becomes by any means acid, as it does in the neighbourhood of towns by dissolving the acid fumes, then this protecting film of oxide is eaten away, the coating of zinc soon disappearing and the sheet iron rusting into holes. When the galvanised iron begins to show signs of deterioration, it is a good plan to at once paint it, and to follow this up periodically. A good paint to use is one of a metallic oxide character. Common tar should not be used, as this is not a good medium for protecting sheet iron.

In fixing corrugated sheets it is usual to have a side lap of one corrugation, as shown in Fig. 175 (a), and this should be arranged the same way up as in the sketch, and not upside down, as one occasionally finds sheets erected. In the latter case, the joints are almost sure to leak. A safer joint is (b), in which two corrugations are lapped over. This makes a much better job, but adds somewhat to the cost, both in labour and material. The end laps of

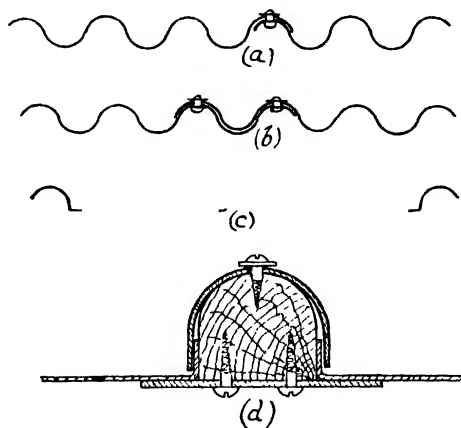


FIG 175.

sheets run about 6 in., sometimes less, and occasionally more. The longer lap is always preferable, especially if the roof is flat. Where much snow is likely to lodge a large end lap is the safest, so as to avoid as much as possible the backing-up of the water. It is usual to fix a washer (made out of about 16 gauge iron) on the rivet before hammering down and snapping. This is to avoid leakage around the rivet. Sometimes rubber washers are used in addition, and on very exceptional occasions canvas packing is placed

between the joints. It should be remembered that, however carefully galvanised iron is fastened to timber, the holes in the sheets are bound to pull a little and get loose on account of the difference in expansion and contraction, due to changes of temperature, between metal and wood. On a wholly iron structure this is not so bad; but even in this the intensity of the sun's heat-rays will cause a greater expansion in the galvanised sheet iron than in the framework underneath.

Tiles are sometimes formed out of galvanised sheet iron, and also out of sheet zinc, as shown in Fig. 175 (c). They are lapped over and nailed or riveted the same as corrugated iron. Sheet zinc for roofing purposes unfortunately has a high degree of expansion and contraction for changes of temperature, and, therefore, should never be fastened together in long lengths. A method that can be followed to overcome this difficulty is explained by Fig. 175 (d). The timber section represents a rafter or roll, to the bottom of which a flat plate is secured. The sheets have the edges turned up on each side, and dropping in between the rolls rest on the flat plate. The caps can be made up in short lengths (say, about 3 ft.), and fitted over roll and edge of sheet, and lapped over each other. No nails or screws should pass through the joints, so as to allow perfect freedom for expansion and contraction.

In the case of curved sheets of either corrugated iron or zinc there is not so much trouble with expansion and contraction, as the change of length is taken up in increased or decreased curvature.

### Roofing Fittings.

The roofing sheet metal worker is called upon to make mouldings, gutters, ventilators, finials, downspouts, and pipe bends of all descriptions, and in addition much intri-

cate work in the ornamental line. We will take, first of all, a few cases of pattern-cutting for

### Moulding or Gutter Angles.

The commonest form of a gutter angle is perhaps of a square elbow for a half-round gutter (Fig. 176). It may

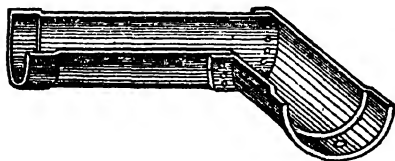


FIG. 176.

be made out of thin galvanised sheet, say 24 to 20 gauge, having a bead or flange along the edge and a soldered joint, or, as in the sketch, made out of 16 or 14 gauge

black iron, riveted at the joint and galvanised or painted afterwards. The setting out of the pattern, which is explained by Fig. 177, is a simple matter. A semicircle is described, as shown, and divided into six equal parts, and the girth line of the pattern made the same length as the semicircle either by calculation or marking along six lengths, each equal to one of the parts on the semicircle. From each of the division points on the girth line a perpendicular is run up, and from the points on the semicircle lines are drawn parallel to the girth line.

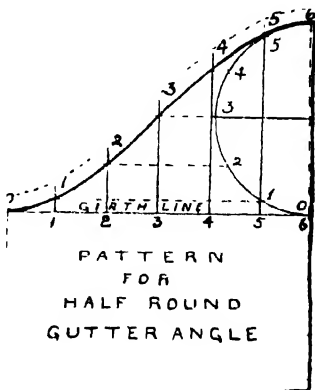


FIG 177.

The intersection of corresponding lines will give points on the pattern curve. Thus, where the line drawn up from 2 on the girth line intersects

the line drawn through 2 on the semicircle will give point 2 on the pattern curve. In the same manner all the other points can be determined. A free curve being drawn through the points, the net pattern is complete. The lap for flanging is added, as shown by the dotted line. The arm of the gutter angle which fits inside will, of course, not require any lap. It will also be an advantage to have the girth of this arm a little less than the other, the side lines of the pattern being cut slightly tapered, as shown, by the two dotted lines running along the sides of the pattern.

A good deal of care is necessary in the flanging, this being best carried out in the case of thick gauges by throwing over when hot. The holes for rivets should be punched in the plate after flanging, the holes for the inside arm being marked from these and punched by the use of a burr.

### Obtuse Gutter Angle.

To set out the pattern for a gutter or moulding angle which is required to fit on or into a greater angle than a right angle, will demand a somewhat different method to that shown in the last case. Thus, suppose an elbow is wanted to fit on to an angle of  $130^{\circ}$ , as in Fig. 178, then some such method as that illustrated by Fig. 179 will have to be used. The shape of the section is first set out and a line E F drawn across the top.

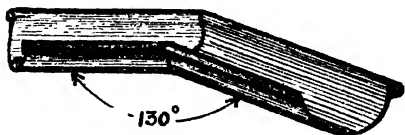


FIG. 178.

Two parallel lines C D and A B are drawn perpendicular to E F, these representing the width of gutter. Across these a line E A is drawn, called the joint line in the figure, making an angle of  $\frac{130}{2} = 65^{\circ}$  with A B. The gutter

section is divided up into any number of parts, such as 0 to 1, 1 to 2, 2 to 3, etc., and lengths equal to these set out to obtain the full girth of the gutter. It will be seen that the gutter section is divided into fourteen parts, hence the total girth of the section as laid out on the girth line of pattern will run from 0 to 14, as shown by the numbers. Through each division point on the section lines are drawn square to E F, and produced until they cut the joint line. From the points where these lines meet the joint line, dotted

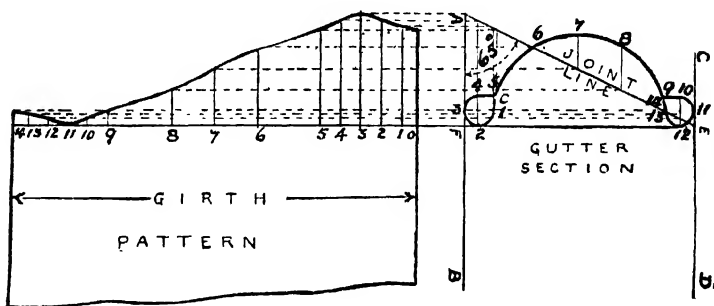


FIG. 179.

lines are drawn down on to the pattern, and through each division point on the girth line square lines drawn to meet them. Thus, consider point 8 on the gutter section, follow the line down to joint line, and then along dotted line to pattern, where it will intersect with the line drawn through point 8 on the girth line. This gives a point on the curve to form the cut of pattern. In the same way all the other points can be determined, and thus the pattern completed. No lap will in this case be needed, the edges of metal being butted together and soldered.

In bending sheets or plates for angles of moulding, care

must be taken to bend them into pairs of right and left hand.

Where the gutter or moulding has many bends, it must be formed to the exact shape of section, or else it will be most difficult to fit the corner joint together.

### Square Angle for O.G. Gutter.

Fig. 180 shows a sketch of an internal angle for an O.G. gutter, and patterns for both internal and external angle-pieces. A section of the gutter is set out as shown on the pattern for an external angle. This is then divided into seven parts—0 to 1, 1 to 2, 2 to 3, etc.—and these lengths measured and set out to give the girth of gutter or width of pattern. From the points on the section, lines are drawn down, and from the corresponding points on the girth line, lines are drawn across. Where these meet give points on the pattern curve, as will be seen. The points are joined up, and thus the cut of pattern obtained. In joining up it should be remembered that where the line on the section is straight, the corresponding part on the pattern will also be straight. Thus 5 to 6 is seen to be straight on the section; hence on the pattern curve the line joining these



INTERNAL  
ANGLE GUTTER

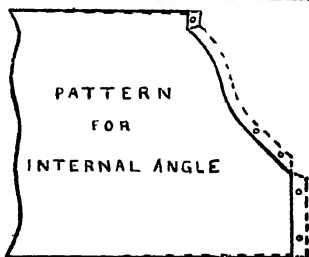
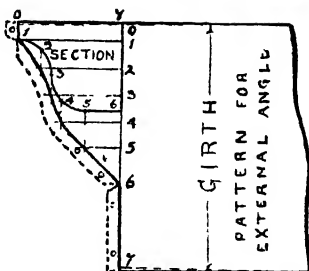


FIG. 180.

two points will also be straight. For heavy sheet iron the laps will be as shown by the dotted lines, and as in former cases flanged over when hot. For light galvanised sheet iron laps will be allowed on the straight parts of cut only; the edges of the curved part butting together, and being soldered from the inside. Laps will, of course, only be needed on one arm of the elbow.

The pattern for an internal elbow can be struck out as above, or, which is much better, when the pattern for the external angle is cut out can be marked off it as shown in the lower figure of Fig. 180. The cut of the end of pattern will be exactly the same as in the external angle, but used in the reversed manner. Laps will be as shown in the figure. Holes can be punched in the laps that will remain straight after the plate is bent, as these will not interfere with the part that has to be flanged over. The pattern for the inside arm should be slightly tapered, as in the half-round gutter angle, and this is shown by the side dotted lines.

It might be as well to here explain that an external angle-piece is an elbow which is supposed to fit *on* a corner, and that an internal angle-piece is an elbow which is made to fit *into* a corner.

### **Obtuse or Acute Elbow for O.G. Gutter.**

An obtuse elbow is one whose arms are extended to an angle which is greater than a right angle ( $90^\circ$ ), and an acute elbow one whose arms are opened out less than a right angle.

The method here given will apply to either case, and, indeed, might have been used for the square elbow instead of that shown in Fig. 180; but for that particular angle-piece the method illustrated by Fig. 181 will not be so good as the one previously explained.



As this problem of jointing together two pieces of gutter or moulding to form a mitre or bevel joint is important, we will fully explain it by means of Fig. 181. To take a concrete case, let us suppose that the arms of the elbow make an angle of  $100^{\circ}$  with each other.

The exact shape of the section must first be set out. The double curve of this being drawn by dividing the straight

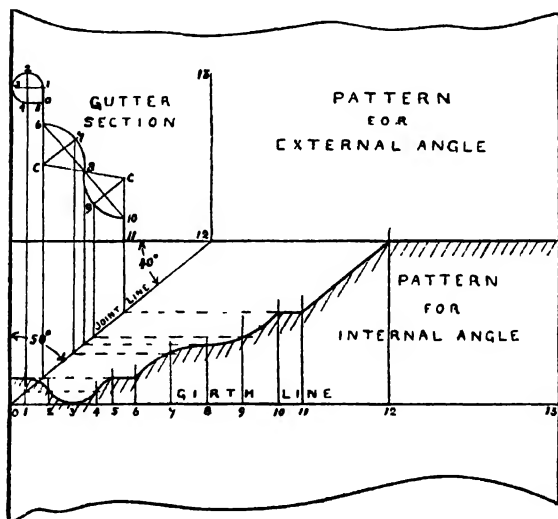


FIG. 181.

line 6 to 10 into four equal parts. Through two of the points, as shown, draw perpendicular lines. Produce line 11 to 10 up, and line 5 to 6 down to meet these lines, thus obtaining points C C, the centres of the arcs. Before drawing the curves in, it is as well to join the two centres by the line C C, and where this crosses the line 6 to 10, will be the meeting point of the two arcs. (Particular notice

should be taken of this construction, as double curves are often required in sheet metal work.) Now to set out the patterns. First a plan of the joint line must be drawn, and as the angle of the elbow is  $100^{\circ}$  the joint line will make  $\frac{1}{2} = 50^{\circ}$  with the outside line, as shown. For construction purposes, however, it will be easier to set the joint-line angle from the back of the section, and a general rule for obtaining this angle will be: "Deduct half the elbow angle from  $90^{\circ}$ ." Thus, in this case the angle will be—

$$90 - \frac{100}{2} = 40^{\circ},$$

and this will be set out as shown in Fig. 181.

The section is divided into parts 0, 1, 2, 3, 4, etc., up to 13, and lines drawn down through each point on to the joint line. From the end of the joint line a girth line is drawn, as indicated, and the exact lengths of 0 to 1, 1 to 2, 2 to 3, etc., from the section set along this line. Lines are now drawn up through each of these points square to the girth line, and where they intersect the corresponding dotted line will give a point on the pattern curve. Thus, for instance, the dotted line which is drawn from the joint line at the foot of the line drawn down through point 9 on the section will intersect the line drawn up from point 9 on the girth line. So with each other pair of lines. If the pattern curve be carefully cut along, the upper portion of the figure will give a pattern for an external angle or elbow, and the lower part a pattern for an internal angle.

It should not be forgotten that, whilst the bending up of this class of work is simple, the highest degree of accuracy in striking out the patterns and in forming the moulding or guttering to the exact shape of section is essential if the parts are to fit together properly. All sheet metal work of an ornamental character, if it is to look well, must be made as neatly as possible, having neither lumps nor hollows nor superfluous solder about the joints.

## Valley Gutter Elbow.

To mark out the shape of sheet to form a right-angle elbow for a square valley gutter (Fig. 182) is an easy matter. The girth is first laid out (Fig. 183) by setting along the width of bottom, depth of sides, and breadth of flanges, the cut for the mitre being formed by making  $a b$  on the pattern equal in length to the line  $A B$

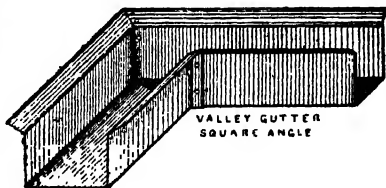


FIG. 182.

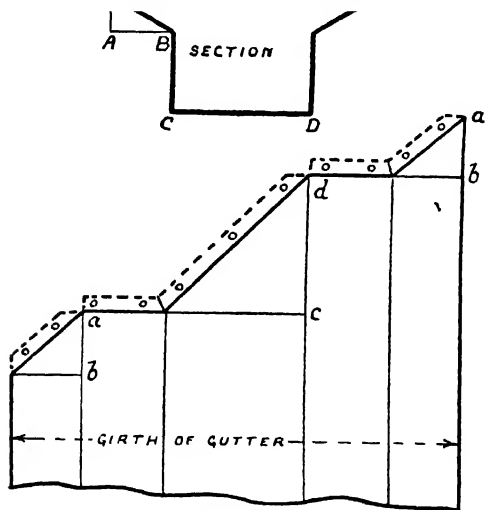


FIG. 183.

on the section, and  $c d$  equal to  $C D$ . The flanges or laps for riveting are added on as shown. After the joint is riveted, it should be carefully soldered along to prevent leakage.

### Special Method for Square Elbows.

Before leaving gutter or moulding angles it will be as well to call attention to a special method that can be applied to square elbows, in the striking out of patterns to form the cut for any shaped section.

The shape of moulding is first set out (Fig. 184) and divided up into any convenient number of parts. Lines

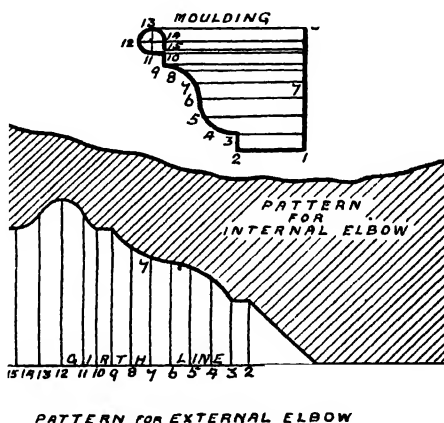


FIG. 184.

square to the back are drawn across through each division point. The girth line of pattern is marked down and lines drawn up square through each division point of this, these lines being cut off equal in length to the corresponding line on the section. Thus, to take one line only, the line 7 7 on the pattern will be the same length as 7 7 on the

section; similarly the lengths of the other lines can be set off.

In practical sheet metal work it is most difficult to project lengths from one view or figure to the other; hence it is always the best plan to transfer the lengths with the compasses, as in the above case.

## CHAPTER XXIII.

ROOFING WORK (*continued*).

## Cornices, Mouldings, and Ridge Caps.

In the previous chapter we dealt with the marking out of patterns for sheet metal moulding or gutters that form a plain mitred joint, and in this chapter we purpose explaining the way in which cornices, guttering, etc., may be jointed, and the patterns laid out when they meet at a double rake.

In Fig. 185 a sketch is shown of a cornice running along the eaves and up the gable of a building. By jointing the corner at right angles in the ordinary way, and then forming another joint to turn the cornice up the edge of the gable, the problem in this case becomes a comparatively easy one.

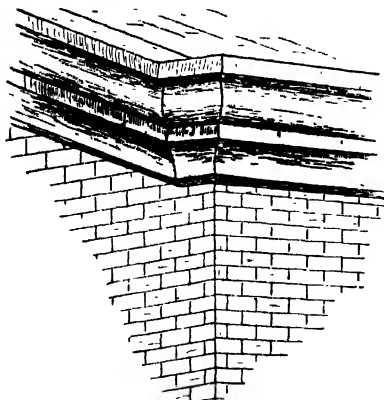


FIG. 185.

An elevation of the moulding is shown in Fig. 186, the roof being pitched at an angle of  $30^{\circ}$ . The section is divided up and numbered, the sum of the lengths 0 1, 1 2, etc.,

up to 9 giving the girth of the moulding.

Two pattern cuts will be required, one for the part of the cornice that is horizontal, and the other for the joint formed by the small horizontal piece at turn of corner and the part of cornice running up the gable edge. The girth of the section is first laid out for the widths of the patterns, and the cross lines drawn as seen in the figure. The cut for the corner mitre will be set out in the ordinary way by making the cross lines equal in length to the correspondingly numbered lines on the moulding section. Thus,  $1\ 1' = 0\ 1$ ,  $2\ 2' = a\ 2$ ,  $3\ 3' = a\ 3$ , and so on for the remaining lines.

The cut for the gable cornice joint will be laid out by making  $2\ 2''$  and  $3\ 3''$  on the pattern each equal to  $a\ a'$  on the elevation,  $4\ 4''$  equal to  $b\ b'$ , and so on for the remaining lengths. The cut on the pattern for the sloping piece of cornice will, of course, be the same as that on the left side of the corner-piece pattern, only reversed.

After cutting the sheet zinc or galvanised iron to the required shape, care must be taken to bend the pieces right and left hand, so that the edges will come together correctly.

Strong joints can be made by carefully soldering on the inside of cornice, and, if required particularly strong, laps can be left on the straight parts of the edge of one pattern

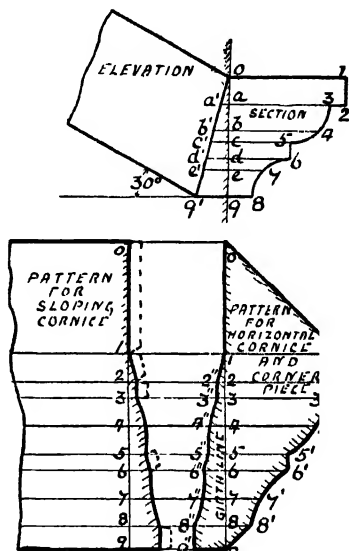


FIG. 186.

(shown by the dotted lines), and these turned on to the insides of the moulding and soldered or riveted as desired.

### Oblique Cornice Joint.

Instead of turning the moulding round the corner and up the gable by two joints, as in the last case, sections of cornices may be made that will come together in one joint at the corner. This particular method of jointing is illustrated by Fig. 187. The shape of one of the mouldings

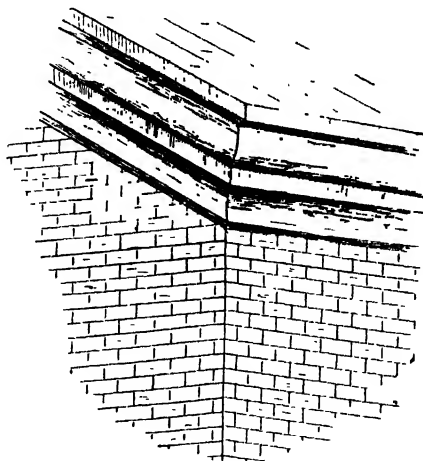


FIG 187.

must first be fixed (in this case the one along the eaves), and the section for the other projected from it.

In Fig. 188 a section of the horizontal moulding is shown set out, and from this the shape of the gable cornice projected. The latter is obtained by drawing a line *SS*, at any part, square to the gable-slope line, through the numbered points on the eaves section, running up lines



perpendicular to it, and cutting these off, to the left of S S, equal in length to the similar lines on the eaves section. Thus,  $a' 1' = 0 1$ ,  $a'' 2' = a 2$ ,  $a^o 3' = a 3$ , and so for the other pairs of corresponding lines. The points obtained are then joined up (as shown by the dotted lines), the resulting figure being the shape to which the moulding for the gable must be made.

In marking the pattern it should be remembered that the cut for the eaves moulding will come out as in the last case—that is, the same as in an ordinary flat square-mitred joint. The cut for the pattern of the sloping cornice will be obtained by first setting down a girth line equal in length to the girth of the projected section—that is, by making  $0'' 1'' = 0' 1'$ ,  $1'' 2'' = 1' 2'$ ,  $2'' 3'' = 2' 3'$ , and so on. The lengths of the construction lines on the pattern are measured from the elevation—that is,  $0'' 0^o$  is made the same length as  $0' 0$ , and  $1'' 1^o = a' 1$ ,  $2'' 2^o = a'' 2$ ,  $3'' 3^o = a^o 3$ ,  $4'' 4^o = b' 4$ , and in the same way for the remaining lines.

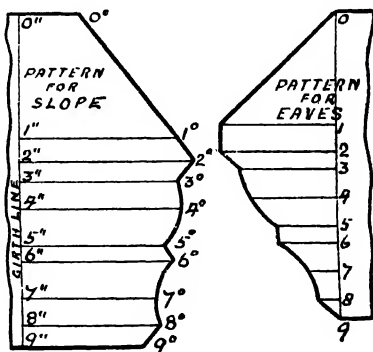
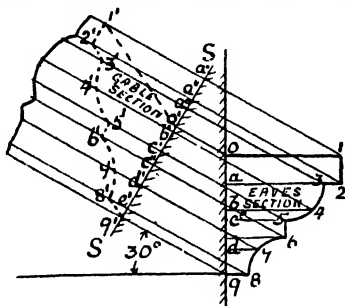
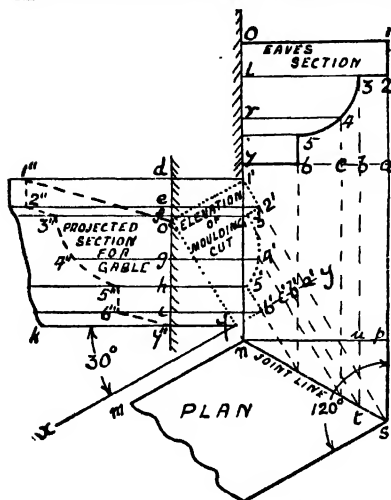


FIG. 188

For the joint to be made properly and with ease, care

must be taken that the setting out is done accurately, and that the sheet metal is bent to the exact shape of the respective sections.



### Double-Rake Moulding Joint.

Where the gable-end of a building is not square to the sides, but is inclined, the problem of connecting the two mouldings with a single joint becomes more difficult than in the last case. It represents, perhaps, one of the most complicated cases of sheet-metal cornice jointing it is possible to have. However, if the reader carefully follows each step in the setting out as shown, he should, even without a very extended knowledge of geometry, be able to accomplish the task of striking out a pattern.

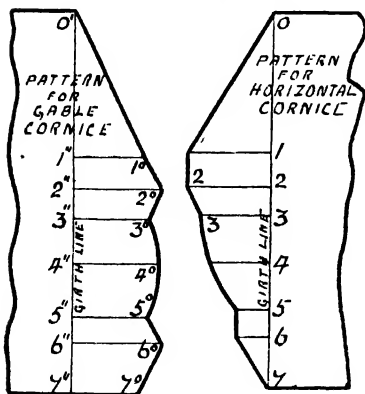


FIG. 189.

with the sides, whilst the pitch of the roof is  $30^\circ$ .

The shape of the section is first set out, and a plan drawn showing the required angle of  $120^{\circ}$ . From each numbered point on the section projectors are run down to the joint line, the line  $n p$  then being drawn square across.

The pattern for the cut on the horizontal cornice can now be set out. First, lay down the girth line, as shown, by making it equal in length to the sum of the numbered parts on the section. Then through each point draw lines square across, and cut these off equal to the lengths of the lines between  $n p$  and the joint line. Thus, 1 1 and 2 2 are each equal to  $p s$ , and 3 3 will be the same length as  $u t$ , the other lengths passing through 4, 5 and 6 being cut off in the same manner.

Before the pattern for the gable-cornice can be laid out, the length of its construction lines must be obtained, this being done by drawing a side elevation of the inclined cornice. Draw  $x y$  parallel to  $m n$ , and then from the latter line run up a perpendicular from  $n$  to intersect  $x y$  in  $7'$ . Now draw the line  $7' k$  at the required angle of  $30^{\circ}$ . Through each point on the joint line run up projectors, and cut these off, above  $x y$ , to the heights of the corresponding lines drawn above 7  $a$  up to the eaves section—that is,  $a' 1' = a 1$ ;  $a' 2' = a 2$ ,  $b' 3' = b 3$ , and so on for the rest of the lines. If the points as found are joined up, it will be seen that the figure (shown marked out by small dots) will be the elevation of the moulding-cut. From this, the projected section for the gable-cornice can be obtained. Draw the line  $7'' d$  perpendicular to  $k 7'$ , and passing through  $0'$ ; then mark off  $d 1''$  and  $e 2''$  each equal to  $0 1$ . Afterwards,  $f 3''$  should be made equal to  $l 3$ , the length  $g 4''$  the same as  $r 4$ , also  $h 5''$  and  $i 6''$  each equal to  $7 6$ . Joining the points up, the figure (shown by long dots) will give the shape of cornice-section, for the gable, that will join on to the given eaves section.

For the pattern of the gable-cornice cut, the girth line

will be measured from the projected section, and it will be seen that the same numbers are used in both section and pattern. The lengths of the construction lines on the pattern are cut off equal to those on the right hand of 7" *d* measured up to the points 1', 2', 3', etc. Thus, on the pattern, 1" 1° = *d* 1', 2" 2° = *e* 2', 3" 3° = *f* 3', and so on for the remaining lines.

In bending into shape, the gable-cornice pattern will, of course, be bent to the projected section, whilst the pattern for the horizontal moulding will be shaped to the eaves section.

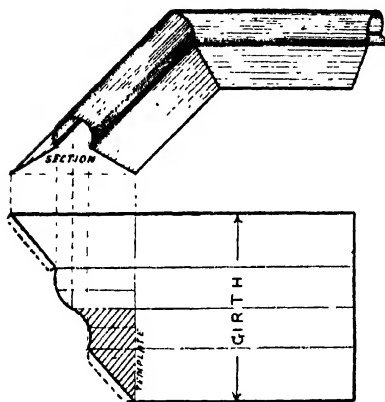


FIG 190.

Although the setting-out in the last three cases has special reference to sheet-metal roofing work, it should be borne in mind that the principles will apply to all kinds of work where moulding or beading has to be fixed in a similar manner.

### Ridge-Cap Elbow.

The setting-out as shown in Fig. 190 needs little explanation. The girth as taken from the section is first laid out, and construction lines drawn through each division point, these being cut off by the respective distances as shown projected down. In practice, it might be here remarked, this method of projecting lengths is hardly permissible, on account of the liability of error and inconvenience of draw-

ing long lines parallel. The lengths should be measured from the section shape and transferred directly to the pattern. It will be sufficient, in practice, to mark out a piece like the shaded portion on the pattern, as this can be used as a template to strike out the remaining part by reversal.

### Ridge-Cap Tee-Piece.

On comparing the shaded parts of the patterns in Figs. 190 and 191, it will be seen that they are exactly the same; hence the template for the elbow can also be used to mark out the patterns for the tee-piece. The template can first be

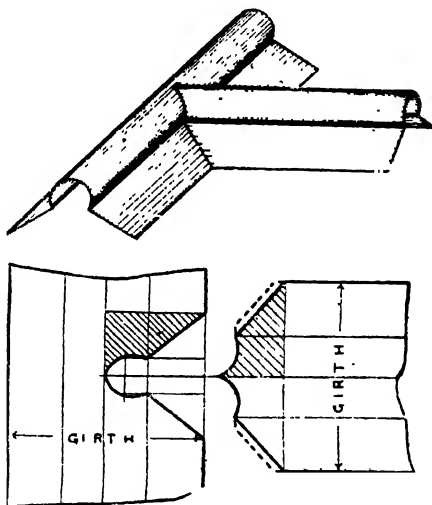


FIG. 191.

fixed in the position of the shaded parts (Fig. 191), and then reversed, to scribe out the other sides. The patterns, of course, could also be struck out by direct measurement, as in the case of the elbows.

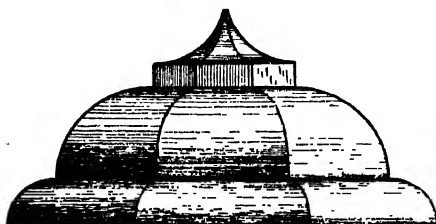
## CHAPTER XXIV.

ROOFING WORK (*continued*).

## Domes, Finials, and Downspout-Heads.

## Dome-Covering.

In cutting out the shape of the segments for a dome-



ELEVATION

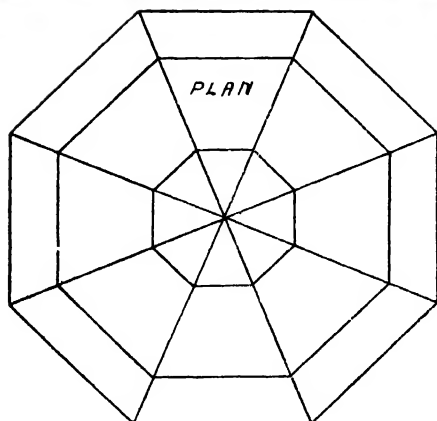


FIG. 192.

covering (Fig. 192), no great skill is required. All the setting-out necessary is shown in Fig. 193. A half-section of the dome is drawn, and divided up into convenient parts, and numbered as seen. The dome being octagonal, the angle that the plan of the joint line will make with the base line will be—

$$\frac{360}{8 \times 2} \quad 22\frac{1}{2}^{\circ}.$$

When the joint line is drawn in at the required angle, the figure below the base line, it should

be noticed, will represent the plan of half a segment.

Lines are run down from the division points across the base to the joint line. The girth line is laid out in the usual way, and construction lines drawn across, these being cut off equal to the length of the corresponding lines drawn between the base and joint lines. Thus, to give one example, line 8° on the pattern is the same length as 8' 8" on the plan, and so with the rest of the lines.

If there is a ridge-roll at the joints, then the width of this must be allowed for in marking out the pattern, one-half the width of roll being set along inside the plan of joint line, which will give the required reduction.

The number of pieces of sheet metal required to make up a segment will, of course, depend upon its size. There should be no trouble, however, to determine this when once the shape of a complete segment is marked out.

If a roll or ridge-cap has to be bent to the shape of a joint, then this can be accomplished by first marking out the exact shape of a joint. This is shown set out at the bottom of Fig. 193.

The joint-line plan and its division points are laid down, and construction lines

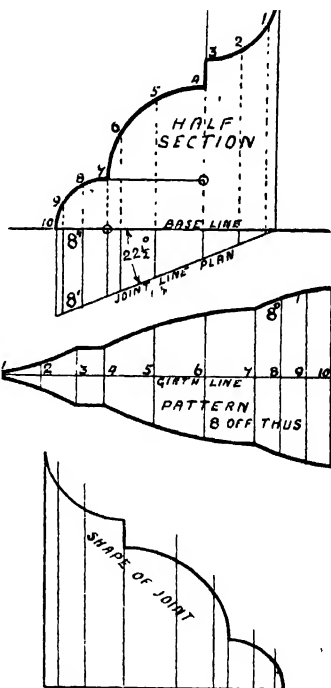


FIG. 193.

run up from the intermediate points, the lengths of these

being cut off equal to the heights of the corresponding line on the half-section. It should be observed that the three curves of the joint shape come out as quarters of ellipses, and, if desired, can be marked out by the trammel method, as explained in Chapter XXI.

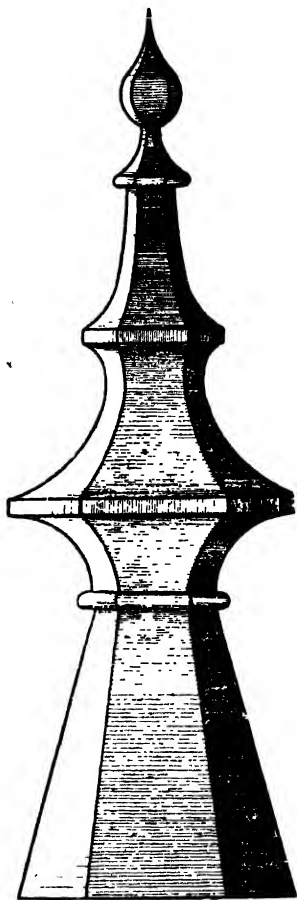


FIG. 194.

### Roof Finial.

There can, of course, be a multitude of designs for a sheet-metal finial, all depending upon the taste of the designer, the limit of cost, and the kind of building that the finial is to be fixed upon. For a high building it should be remembered that small details of ornament on the finial are a waste of time and money, as they are, of course, not noticed from the ground.

A very simple form of hexagonal finial is shown in Fig. 194. It can be made out of either copper, brass, zinc, or galvanised sheet iron, the latter two metals being the ones usually chosen.

The half-sectional elevation and the pattern for one of the strips are shown set out in Fig.

195. After having drawn in the shape of the section as



seen, the curves that form the outline are divided up into a convenient number of parts; there being seventeen in the present case. Lines are then drawn at points *a*, *b*, *c*, and *d*, making angles of—

$$\frac{360}{\text{twice number of sides}} = \frac{360}{12} = 30^\circ$$

with the cross lines; these really being plan views of one of the joint lines. Lines are then drawn down through each point parallel to the centre line on to one of the 30° lines.

For the strip pattern the girth line is first stretched out, its total length being made up by adding together the lengths of the different parts, as numbered on the outline in the sectional elevation. Lines are then drawn across the girth line through each numbered point, and the lengths of these cut off equal to the corresponding lines in the elevation between base and joint lines. Thus, for example, the lines 6 6', 8 8', and 9 9' on the pattern will be respectively equal to the lines 6' 6'', 8 8', and 9' 9'' on the elevation. In exactly the same way all the other lines required for marking the width of the pattern at the different parts can be measured from the elevation

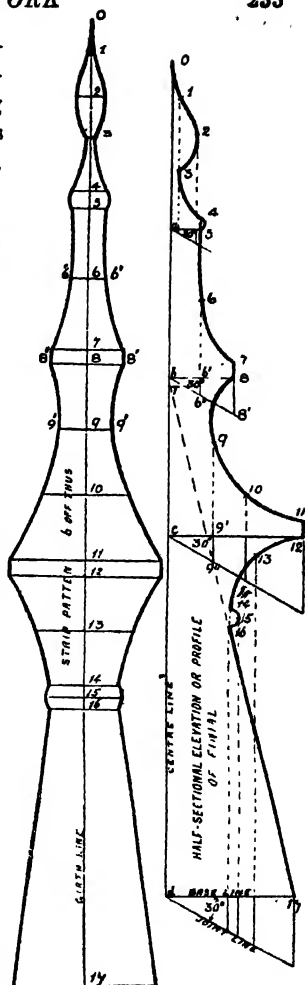


FIG. 195.

It will be noticed that

there are four  $30^\circ$  lines in the elevation, the object of the three top ones, of course, being to avoid having to run the dotted lines for the widths all the way down to the base line.

Instead of having the whole strip in one piece, it can, if necessary, be divided up into any number of parts, depending upon the size of the finial.

After the pieces are connected, the sections can then be jointed together.

Sometimes the base part of the finial is made separately, which, it can be seen in this case, will come out as a frustum of a hexagonal pyramid. The apex of a complete pyramid can be found by producing the line 17 to 16 (Fig. 195) up to meet the centre line at T. The setting out of this frustum is shown separately, and to a smaller scale, in Fig. 196. The point *l* is swung around *d* to *l'*, and joined to the apex T. Then taking T as centre and T *l'* as radius, the arc is described as shown. The compasses are

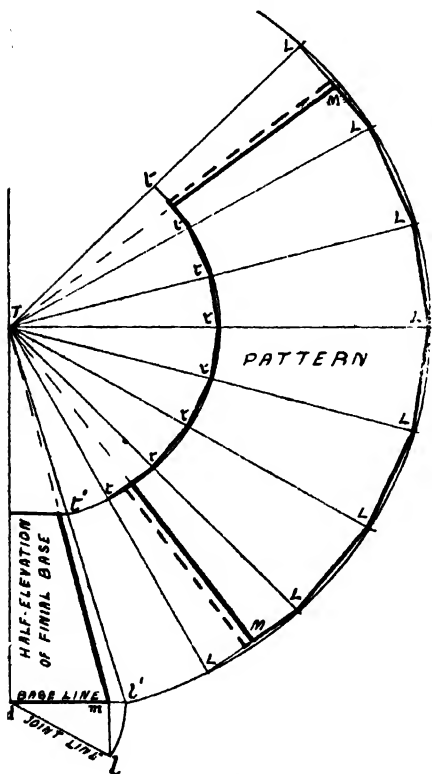


FIG. 196.

now set to twice the length  $lm$ , and the points  $L$  stepped around the arc. It is a good plan to mark off one side more than is required (in this case seven), and then bisect the two end parts to obtain the seam exactly up the middle of a side. These joint lines are marked  $TM$  in the figure. The line  $Tt'$  will give the radius for cutting off the points to form the inside part of pattern shown by the lines  $tt$ .

In making up the finial the strips should first be bent to the required shape of section—that is, the centre line of the strip should be formed to the outline in the elevation (Fig. 195). The strips are then all tacked together with solder, and after carefully testing the finial to see that it is symmetrical and without twist, the joints soldered up, as much of this being done from the inside as possible.

### Downspout Head.

A downspout or hopper-head lends itself admirably for treatment by ornamental work in sheet zinc or galvanized sheet iron. In this case, as in the last, the shape of moulding chosen may be of any section to suit the individual taste and estimated outlay. A simple design is that shown in Fig. 197; its form in plan being that of the five equal sides of an octagon.

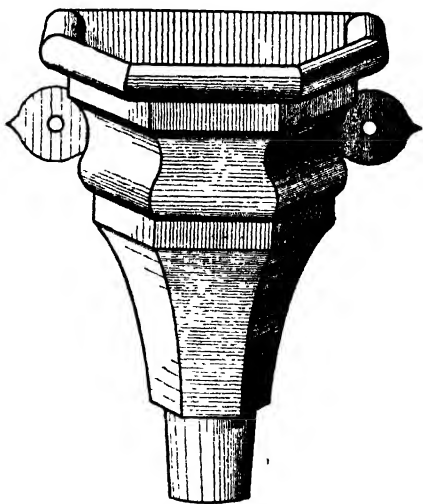


FIG. 197.

Before the pattern for a strip can be marked out, the shape of the moulding must be determined, as shown in

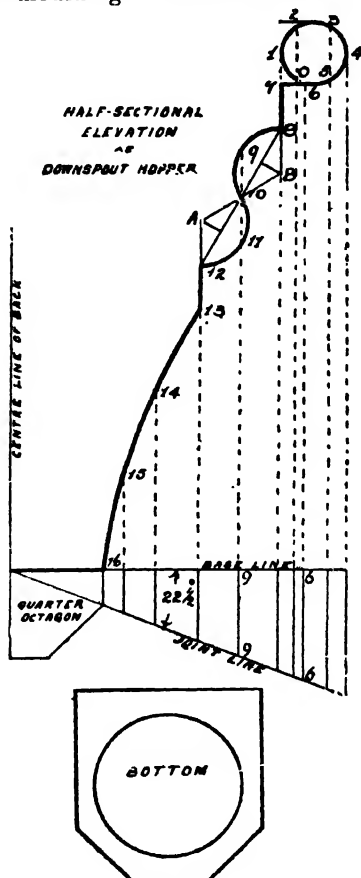


FIG. 198.

Fig. 198. The centres for the double bend or O.G. part can be found by joining points 8 and 12, and dividing the line

into four equal parts, then drawing lines square through the two end divisions until they meet the lines drawn up from 12 and down through 8 in points A and B. If A be joined to B, then the point where the two arcs run into each other will be at the point marked 10. Having drawn in the outline, it must then be divided up conveniently for measuring (say, in this case, sixteen parts), and a base and joint line drawn. As previously mentioned, the angle that the joint line should make with the base line will be—

$$\frac{360}{\text{twice number of polygon sides}} = \frac{360}{16} = 22\frac{1}{2}^{\circ}$$

Perpendiculars are drawn through each point down to the base line, and then produced across to the joint line.

For the pattern of a front strip the girth line is first set down, its total length being obtained by carefully measuring off the parts between the numbers in the elevation and marking along as shown in the pattern (Fig. 199). Lines at right angles to the girth line are drawn through each point, and these cut off equal to the length of the corresponding line measured between the base and joint lines in the elevation. Thus, to give two examples, which should make it clear, the lines 6 6' and 9 9' on the pattern will be respectively equal to lines 6 6 and 9 9 as seen between the base and joint lines on the elevation. In the same way, all the other lengths for the pattern can be measured and marked off. It should be noticed that several of the lines are the same length; also that the lines 7 to 8 and 12 to 13 on the elevation being straight, the corresponding part on the outline of pattern will also be straight. Having found all the points for the cut, they are carefully joined up, and the strip pattern is complete.

The width of the side strips at the top will be made the same as that of the front strip, the back line being drawn parallel to the girth line.

It will be readily seen that the three side curves of the patterns are all the same: hence in practice it will only be

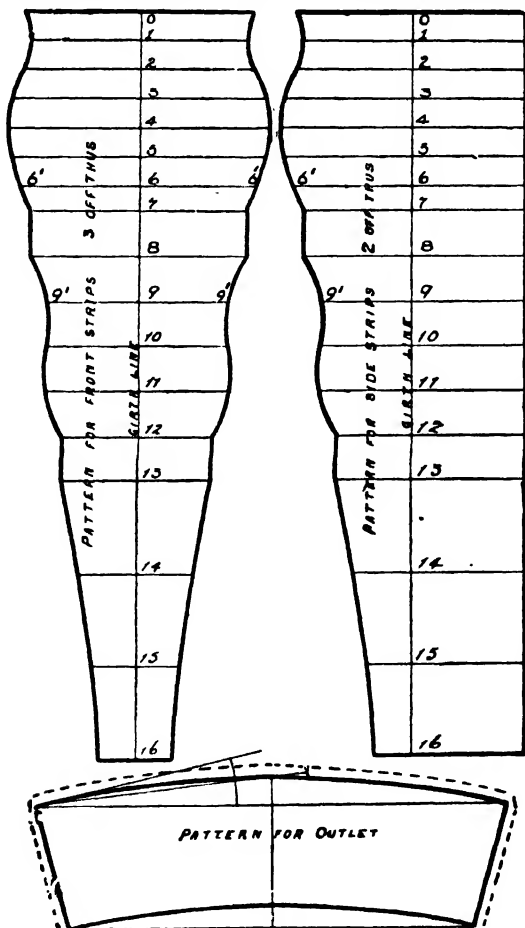


FIG. 199.

necessary to mark out one curve, the others being scribed from this.

The strips will be shaped and tacked together as in the last case, the complete soldering-up being done along the joints on the inside.

The shape of the back of the hopper can be determined from the elevation, or marked off directly after the five strips are soldered together. Lugs should be left on each side of the back, as shown in Fig. 197.

The shape of the bottom piece is shown in Fig. 198, and that for the outlet in Fig. 199, the pattern for the outlet being marked out by one of the methods explained in previous chapters.

## CHAPTER XXV.

### VENTILATOR AND CHIMNEY-POT BASES, HOPPERS, ETC.

A VERY common form of base for a ventilator or cowl is that shown in Fig. 200, and known as a "tall-boy" base.

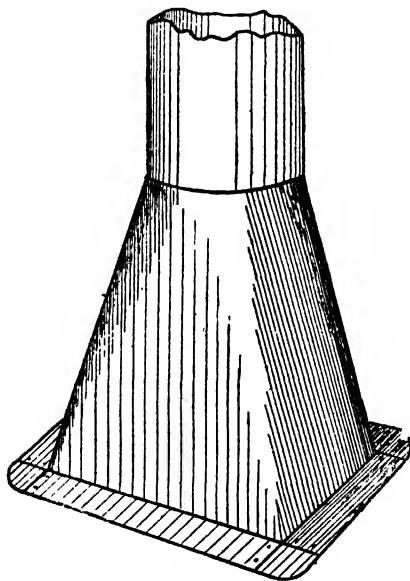


FIG. 200.

It is either square or rectangular at the bottom, and



circular at the top. On examining the plan in Fig. 201, it will be seen that the curved part of the article  $t\ 0\ 3$  will be exactly a quarter of an oblique cone whose apex may be considered to be at  $t$ . Four of these equal segments will, of course, make up the curved portion of the surface; the remaining parts being flat triangles.

In making the pattern, a half-elevation and quarter-plan is first drawn (Fig. 201). The quarter-circle in plan is divided into three equal parts, and the division points joined up to  $t$ . The point  $b$  is now swung around  $d$  as centre on to the base line, and connected up to  $e$ . To get the true lengths of the lines, of which  $0\ t$ ,  $1\ t$ , and  $2\ t$  are the plans, their lengths are set along the base line from  $0$  and joined up to  $e$ ; the respective true lengths, therefore, being  $0'\ e$ ,  $1'\ e$ , and  $2'\ e$ . The middle line  $B\ 3$  of the pattern will be made equal in length to the line so named in the elevation; then  $T\ T$ , drawn at right angles, and the lines  $B\ T$  cut

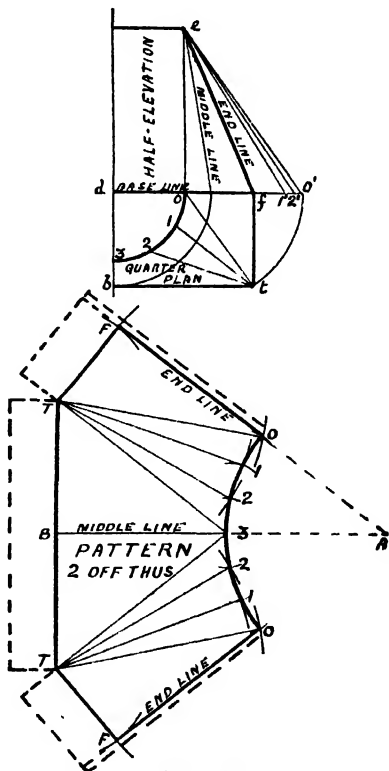


FIG. 201.

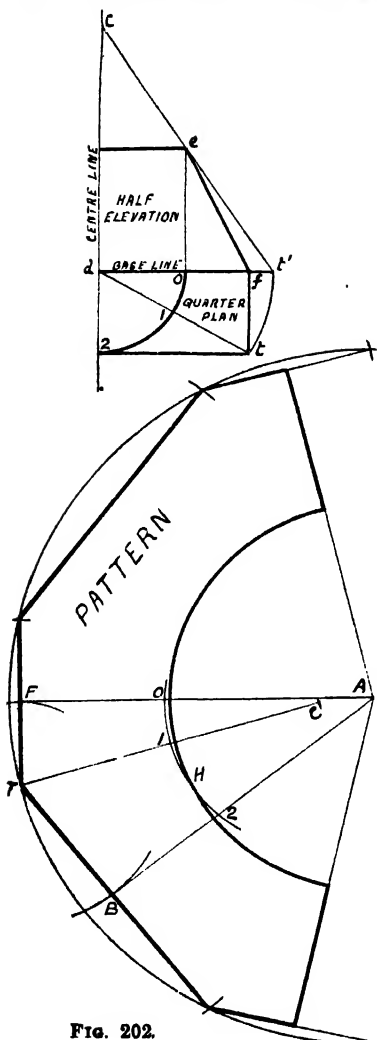


FIG. 202.

off equal to  $b t$  from the plan. With centre  $T$  and radii respectively equal to  $e 2'$ ,  $e 1'$ , and  $e 0'$ , arcs of circles are described. Then opening the compasses to the length of one of the arcs (say 3 to 2) in the quarter-plan, and commencing at point 3 on the pattern, the points 2, 1, and 0 are obtained by cutting the first drawn arcs. The compasses are now set to the length of the end line on the elevation, and with 0 on the pattern as centre, an arc drawn (shown passing through  $F$ ); this being cut by another arc which is described from point  $T$ , with radius equal to  $t f$ ; and so the point  $F$  is obtained. An even curve joining up the points 0, 1, 2, etc., is drawn, and allowances put on the sides for grooving, and on the bottom for the flange, and the pattern is complete.

After having ob-

tained one-half the pattern, it will be quite accurate enough for practical work to produce the lines B 3 and F 0 until they meet in A, and use this as a centre in a similar way to that explained in connection with Fig. 202. If the tall-boy base is square at the bottom, then a portion of the pattern for one-eighth of the surface will be all that is required to obtain the centre A; the line down the middle of the corner meeting the line along the centre of a side.

After the base has been formed into shape, grooved-up, and the bottom flange bent over, corner plates are riveted on to the flanges as shown in Fig. 200.

Another method for marking out the pattern, which is quite good enough for ordinary practice, is shown in Fig. 202. The line  $d t$  in the plan is swung around  $d$  on to the base line, the point  $t^1$  then being joined up to  $e$ , and produced to meet the centre line in  $c$ . The compasses are set to  $c e$  on the elevation, and taking a point C on a line like C T in the pattern, the arc 0 to 2 is drawn. The lengths 1 to 0 and 1 to 2 are now made equal to the lengths of the correspondingly numbered arcs in the quarter-plan. The line C T is measured off equal to the line  $c t^1$  in the elevation. The compasses are next fixed respectively to the radii  $t 2$  and  $t f$ , and the arcs at B and F described. Lines are then drawn touching these arcs, and passing through the points 0 and 2 to meet in A. This gives what may be called an approximate centre for the describing of the pattern. Taking A as centre and A T as radius, the part circle is drawn; then commencing at T the sides and ends are stepped along as shown. The end lines of the pattern are best obtained by marking full end lengths on the arc, bisecting them, and then joining up to A as shown in the figure. The inside curve of pattern is marked out by taking A as centre and A H as radius (this being the average between A 0 and A 2), and running around to meet the seam lines. Allowances as required must, of course, be put on

as in the last method. It will be observed that in this case the pattern (Fig. 202) is developed for the whole surface.

### Hopper or Hood with Flat Back.

A form of hopper to fit against a wall (Fig. 203) having a square or rectangular top, and a circular bottom, can have its pattern set out in the same way as the tall-boy base.

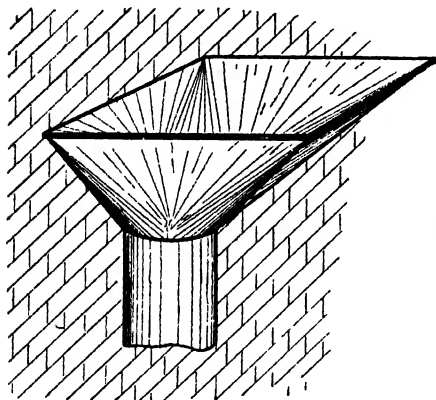
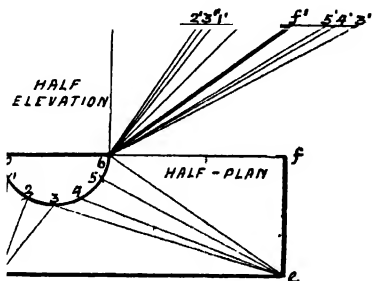


FIG 203.

All the necessary marking out is shown in Fig. 204. To obtain the pattern lines a half-elevation and a half-plan are first drawn, the lines  $e\ 5$ ,  $e\ 4$ ,  $e\ 3$ ,  $b\ 3$ , etc., being set along the top line from  $d$  and joined up to point 6. The pattern is struck out by commencing with line 6 F, which is made equal in length to 6  $f'$  from the elevation. E E

is then drawn square to 6 F, and F E cut off equal to  $e\ f$ . Now with E as centre and radii respectively equal to 6  $5'$ , 6  $4'$ , and 6  $3'$ , describe arcs of circles (as seen passing through points 5, 4, and 3). Then with the compasses set to a distance equal to one of the arcs in plan, say, 3 to 4, and commencing at 6, cut the first drawn arcs, thus determining points 5, 4, and 3. Again, with E as centre and  $e\ b$  as radius, draw an arc (shown passing through B), and with 3 as centre and 6  $3''$  as radius, cut this and so fix the point B. Having found B, now

use this as a centre, and with radii  $6\ 2'$ ,  $6\ 1'$ , and  $6\ 0'$ , draw the remaining arcs, cutting these as before, and thus determining points 2, 1, and 0. Then taking 0 as centre, and radii equal to  $6\ d$  from the elevation, describe an arc (shown passing through A), and cut this by using B as a centre, and  $b\ a$  as radius, thus fixing the point A. Join the points 0, 1, 2, etc., by an even curve, and the other lettered points by straight lines, and the net pattern is complete.



The above pattern has purposely been set out without showing any construction lines on its figure, as all that is required in workshop practice is to get the correct outline, and by as few lines as possible. It should also be noticed that there is really no need to draw the construction lines as shown in the plan and elevation, all that is wanted being the exact distance between the points, such as 5 and e for setting along the

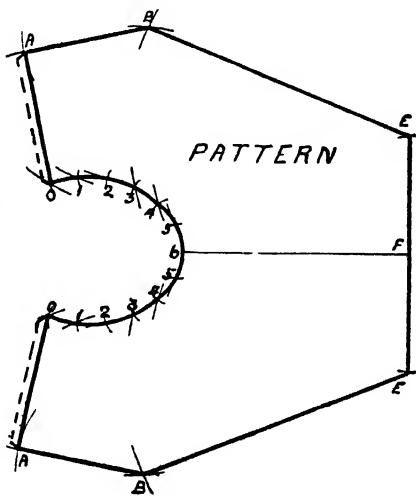


FIG. 204.

top line, and the distance between the points 6 and 5' for obtaining points on the pattern outline. (These remarks, it might be here observed, apply to all classes of patterns.) Any allowance required for seaming, wiring, or beading must, of course, be added to the net pattern.

### Article with Square Top and Round Base.

An article or part of an article may have a round base and a square or rectangular top, as seen in Fig. 205. Its pattern can be developed by treating the curved portions of the surface as parts of oblique cones, and the flat parts as triangles.

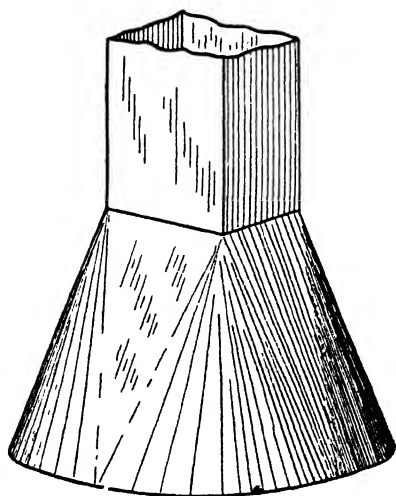


FIG 205.

The setting out of the pattern is explained by Fig. 206, in which a quarter-plan and half-elevation is shown. The quarter-circle is divided up into four equal parts, and the lines  $b\ 1$  and  $b\ 2$  set along the base line from point  $t$  and joined up to  $t'$ . A middle line  $T\ 0$  of the pattern is laid down and made equal in length to  $t'\ 0$  from the elevation. A line is now drawn through  $T$  square to the line  $T\ 0$ , and  $T\ B$  cut off equal to  $t\ b$  from the plan. Now, using  $B$  as centre and radii respectively equal to  $t'\ 1'$  and  $t'\ 2'$ , arcs of circles are drawn as shown. Then setting the compasses to the length of one of the arcs in plan, say, 1 to 2, and commencing at 0, the points 1, 2, etc., are

marked. The triangle T B O is next set out, its construction being simple, and a repetition of the first part of the pattern. An approximate centre in this case can be found, as with the pattern in Fig. 201, by simply producing the lines O T and 2 B until they meet, as shown by the dotted lines.

If the top of the article is rectangular or polygonal in form, its pattern can be struck out as above, but in these cases a greater number of lines would have to be used. Also, if the centre of the top does not come vertically over the centre of the bottom, the pattern can be readily marked out with the same method, the only modification being the same as that applied to Fig. 204.

### Ventilator Base of Pyramid Shape.

A ventilator base may be of the form shown in

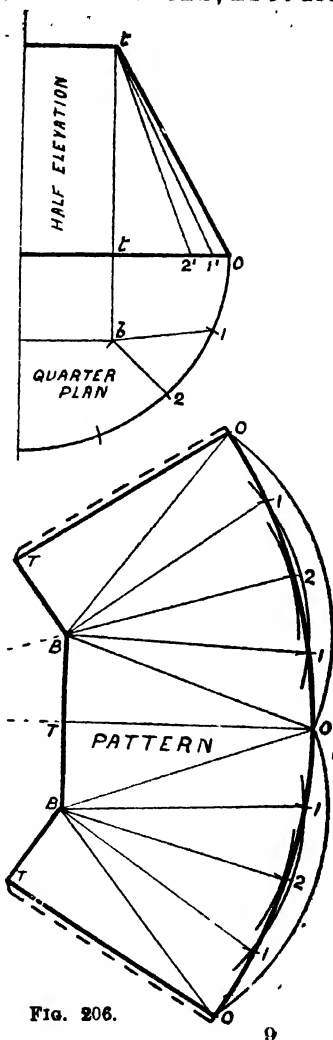


FIG. 206.

Fig. 207, which, it will be seen, amounts, geometrically, to the fitting of a cylinder on to a square pyramid concentrically.

The pattern cuts, both for the pyramid and the pipe surfaces, are shown struck out in Fig. 208. A half-elevation is drawn, and a line making  $45^\circ$  with the base line set down, this being cut off by the line  $O\ 2$ , which is drawn square to the base line. The arc  $O'\ 2'$  is now described, and it will thus be seen that the figure  $O'\ 2'\ 2\ 0$  can be taken as representing one-eighth of the

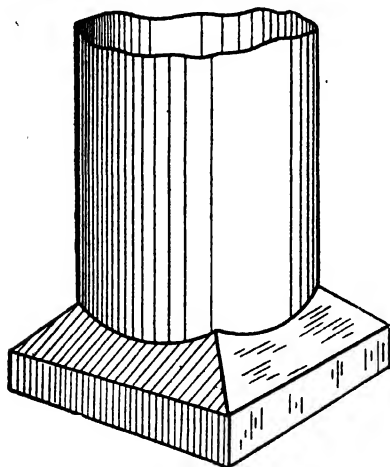


FIG. 207.

complete plan of the ventilator base. Line  $O\ 0''$  is produced to meet the centre line in  $c$ . The line  $O\ 2$  is bisected, and lines  $d\ 1$ ,  $d\ 2$  swung on to the base line about  $d$ , and the points  $1^0$  and  $2^0$  joined up to  $c$ . For the pattern, the compasses are opened out to the length  $c\ 2^0$ , and a circle described as shown. Five sides are now stepped around the circle, each side,  $2\ 2$ , being equal in length to twice the line  $O\ 2$  from

the plan. The last two sides are now bisected, so that to make up the complete pattern there will be three full sides and two half-sides. Each side is now divided into four equal parts, and from the division points lines drawn to the centre  $C$ . The compasses are next set respectively to the radii  $c\ 0''$ ,  $c\ 1''$ , and  $c\ 2''$ , and the three arcs drawn on the pattern to cut the radial lines. Where these arcs intersect the correspondingly numbered line will give a point on the curve. The points are then joined up, such



as 0", 1", and 2", with even curves, and the net pattern is complete. (It is as well to remember that the inner curves are parts of an ellipse, as in many cases they can be marked out by a much simpler method.) Allowance is then put on the pattern for the base flange, corner laps, and side seams.

If it is desired to run the seam down a corner instead of the middle of the side, as shown, then, of course, four full sides would have to be marked out, and not three full and two half-sides as on Fig. 208.

For the cut on the bottom of pipe a girth line is first stretched out by setting along alternately the lengths of arcs 0' 1' and

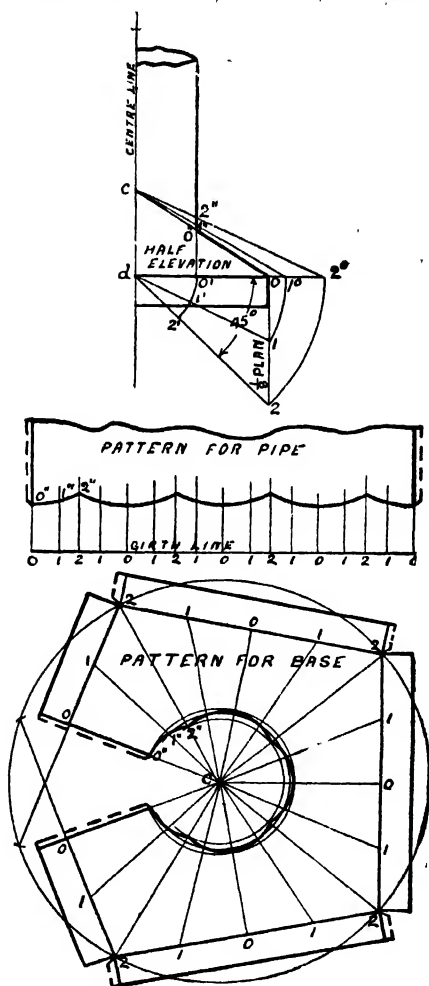


FIG. 208.

1' 2". Lines square to the girth line are then run up from each point, and these cut off respectively equal 0' 0", 0' 1", and 0' 2" from the elevation. The new-found points are then joined up to form the curve. It is as well to remember,

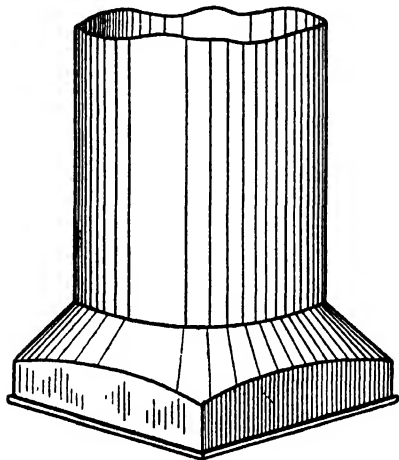


FIG 209.

and it will act as a test for the accuracy of the setting out, that the lengths of the curves 0' 1" and 1' 2" should be the same both on the pipe and base patterns.

### Ventilator with Conical-Square Base.

Sometimes a ventilator base follows the design shown in Fig. 209, which it is not difficult to imagine represents the intersection of a round pipe and cone for the top, and a cone and square pipe for the bottom.

The patterns can be struck out in the way shown in Fig. 210. The half-elevation and part plan are drawn as in the

last case. The arc 0 3 is divided into three equal parts, and the division points joined to *d*. Lines *d* 1', *d* 2', and *d* 3' are turned around on to the base line, and perpendiculars run up to meet the line 0 *c* in points 3'', 2'', etc. The pattern for the conical part is obtained by fixing the compasses to the length *c* 0 describing the arc as shown, and setting along it twelve lengths each equal to the length of one of the corresponding arcs in the plan. After the radial lines are drawn in, the compasses are set respectively to the lengths *c* 0'', *c* 1'', etc., in the elevation, and the arcs on the pattern drawn. Where these cut, the same numbered line will give points on the curve, which can be joined up as shown. The inner curve of the pattern is, of course, marked out by using a radius equal to *c* *t* from the elevation.

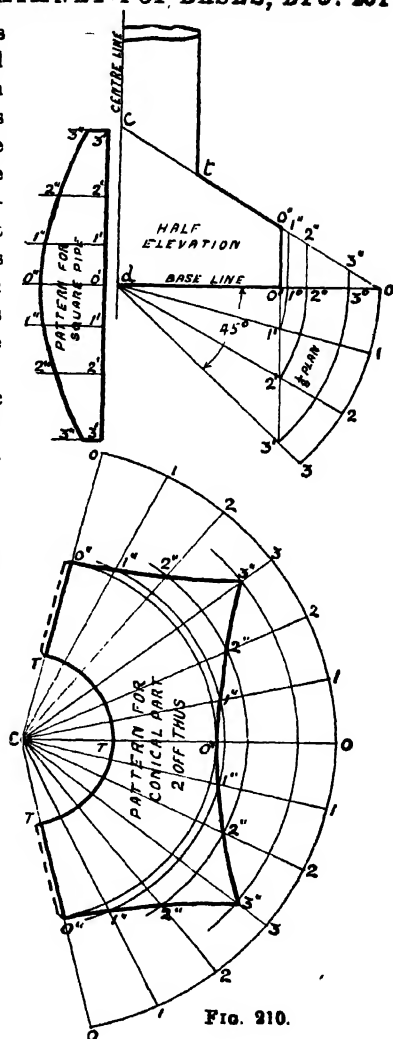


FIG. 210.

The pattern for one side of the square base is shown set at the top of Fig. 210. Here the line 3' 3' is made twice the length of 0' 3' from the plan, the division points being the same. Lines are drawn square through each point, and cut off respectively equal to 0' 0", 1° 1", 2° 2", and 3° 3" from the elevation. The resulting curve is (to those who understand geometry) a hyperbola, and may be set out by other methods common to that curve. None, however, are simpler than the one shown.

Very many different kinds of bases for ventilators are made; but sufficient has perhaps been shown to explain the general principles involved in the marking out of the patterns for flat-bottomed bases. The above can easily be modified to cover the setting out for bases resting on the ridge and sides of a roof.

## CHAPTER XXVI.

## SHIP VENTILATORS, ETC.

VENTILATORS for ships are made in many shapes, forms, and sizes, one of the commonest kind being that shown in Fig. 211. It is usually made of iron, and occasionally of copper or brass.

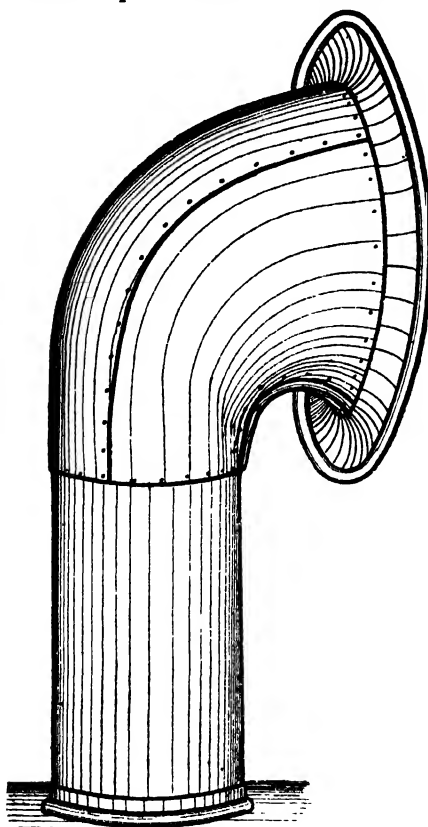
Several methods are in vogue for marking out the plate patterns, according to the practice of the particular locality. As previously stated, in work of this character that has to be hollowed or stretched, it is impossible to set out the patterns that they will work out dead true to shape. The most that can be hoped for is to get as good an approximation as possible, and at the same time take care that the pattern is slightly on the full side.

In Fig. 212 a side elevation of a bell-mouthed ventilator is shown. Its body is formed of four pieces, two cheeks and the throat and the back parts, the bell-mouth being made up in three pieces.

For the cheek pattern the simplest plan is to take the elevation of the body as the shape of the pattern; the only modification required being that shown by the dotted line,  $e l k$ . The point  $l$  can be obtained by making the line  $m n$  equal in length to half the mouth diameter, that is,  $r e$ . Drawing  $n t$  to touch the semicircle on  $a f$ ; cutting off  $t p$  equal to  $t n$ , and then making  $r l$  equal to  $o p$ , as shown by the construction lines. An arc of a circle is then drawn through the points  $e l$  and  $k$ .

Before attempting to strike out the patterns for the back

and throat pieces the elevation of the two joint lines must first be drawn. Divide the curves *a c* and *f k* each into, say, three equal parts, and on the four lines that join the division points describe semicircles, as shown. Now mark



the middle points of the semicircles, such as *s* and *u*, and set around the arc on each side a length equal to half the diameter of the respective semicircles. Thus the arc *s 4'* will be equal in length to *r c*, and the arc *u 3'* equal to *v d*, and so for each of the other two semicircles. Perpendicular lines, such as *4' 4* and *3' 3*, are then drawn from the points on the semicircle to their diameters, and thus points on the joint lines obtained. These are connected with an even curve, as shown by the dotted lines, which will then give an elevation of the two side seams.

For the back pattern, a centre line *A E* is marked down, equal in length to the re-

FIG. 211.

spective parts of the curve  $a e$  in the elevation. The line  $D 3$  is set off equal in length to the arc  $d 3'$ , and the line  $B 2$  equal to arc  $b 2'$ . In the same way the other points, 1 and 4, are found. To get the lengths of the side curves on the pattern, a line,  $c 0$ , is first drawn across the two curves in the elevation, as shown; the point  $c$  being the middle of the back curve, and the line  $c 0$  being drawn by the eye, to make as near as possible equal angles with the two curves. The parts of the joint line  $0 1$  and  $0 4$  are carefully measured along, and their lengths set above and below the point  $0$  on the outside line of the back pattern. In this way the points 1 and 4 are obtained. Arcs of circles,  $4 E 4$  and  $1 A 1$ , are then described to form the ends of the pattern. It should be remembered that when working up the plate for the back, that the centre will lengthen a little and the sides contract some-

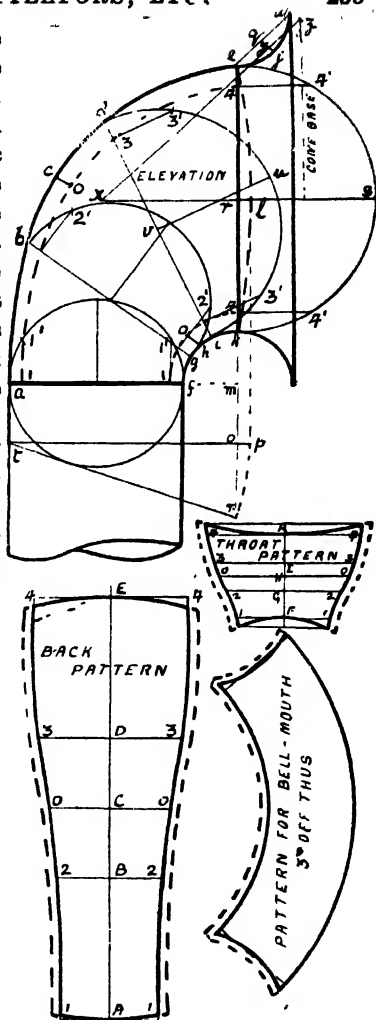


FIG. 212

what; hence the side-curves of the pattern should be made slightly longer than measured from the elevation. This is best allowed for by making the arcs 4 E 4 and 1 A 1 somewhat flatter than they would be if drawn exactly through the three points as found.

The throat pattern can be set out in identically the same manner as that for the back, and so that the reader may the more readily follow the construction, the same numbers for the outside curves have been chosen. In this the centre line, F K, on the pattern is the same length as  $f k$  on the elevation, and the lines, F 1, G 2, etc., equal in length to the arcs  $f 1'$ ,  $g 2'$ , etc. The outside curves of the pattern will be the same length as the throat seam line; O 1 and O 4 on the pattern being made equal in length to O 1 and O 4 on the elevation. In working up the throat plate the outer edges will, of course, have to be stretched: hence they will lengthen somewhat, so that it is as well to keep F K the same length as  $f k$  on the elevation, but to draw the arcs 4 K 4 and 1 F 1 on the pattern slightly flatter, and, consequently, reduce the lengths of the side curves somewhat. The exact amounts to allow on or take off, as the case may be, are matters of experience, or of difficult calculation, the main thing being to keep on the right side, as, in any case, some small allowance must be made for trimming.

If for a large head, the bell-mouth will be made in several pieces; in the present case three have been chosen. The pattern will come out as part of the surface of a cone. The first thing, then, is to find the slant height of the cone, and thus the radius for the pattern. Join  $e$  to  $w$ , and from the middle point  $q$  draw the perpendicular  $q j$ . Make  $j y$  one-third of  $q j$ , and through the point  $y$  draw the lines  $z x$  parallel to  $w e$ , to meet the axis of the supposed cone in  $x$ . The line  $j z$  is made equal in length to the arc  $j w$ , and thus the slant height of the cone is determined. The line  $x z$  is now used as the radius for the outer curve of the bell-



mouth pattern; the length of this curve being made equal to one-third the circumference of the cone base circle. In working up the piece of sheet for the bell-mouth, it will be found that the draw at the ends will not be uniform; consequently it will be necessary to allow a little on the ends of the pattern, as shown by the arcs

The allowances for the joints are added to the back and throat pieces, and also to the inner side of the bell-mouth pattern.

The beading around the bell-mouth is formed either by wiring or split-tube, as shown in Fig. 213.

### Small Ventilator Heads.

The body of a small head may be worked up from one piece, in much the same manner as a copper kettle-

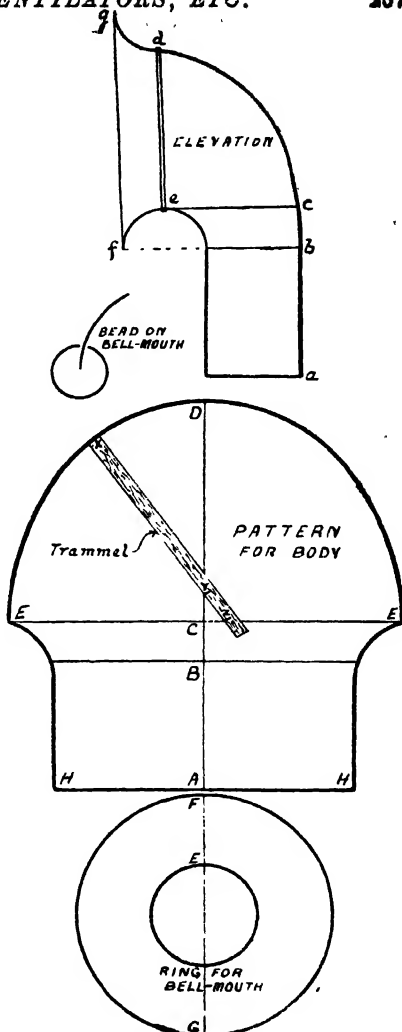


FIG. 213.

spout. In Fig. 213 an elevation of a small head is shown. To mark out the pattern the centre line,  $A D$ , is drawn the same length as the curve  $a d$ , the lengths of the intermediate parts also corresponding to those of the elevation. The line  $A H$  is made equal to half the circumference of the ventilator shaft-pipe, and  $C E$  cut off equal to one and a half times the length of  $c e$  on the elevation. The outline of the top part of the pattern comes out as a semi-ellipse; and this can, perhaps, be best marked out by what is known as the "trammel method." On a strip of hoop-iron or a wooden lath mark from the end a distance equal to the semi-axes, or diameters, of the ellipse; in this case  $C D$  and  $C E$  respectively; thus obtaining two points like  $Y$  and  $Z$ , as shown on the sketch of trammel in Fig. 213. Fix the trammel in several successive positions, always keeping the points  $Y$  and  $Z$  on the lines  $C D$  and  $E E$  respectively, and mark the position of  $X$ ; thus points for the required ellipse will be obtained, and when joined up with an even curve, will give the boundary of the top portion of the pattern, as shown. A curve is now run from  $E$  to join on to the pipe portion of the pattern.

For the bell-mouth, a ring in this case will be best; its diameter,  $F G$ , being equal to  $f g$  in the elevation. The width of ring  $F E$  will have to be somewhat larger than the length of arc  $f e$ , to allow for draw. This width can be calculated, but it will be sufficiently accurate to make  $F E$  equal to about one and a quarter times  $f e$ . The bell-mouth can be fixed to the body by making a knocked-up joint.

An enlarged view, showing the method of fixing the bead, which is usually split-tubing, is also shown in Fig. 213.

### **Irregular Circular-ended Tapering Article.**

A ship's ventilator may also be constructed in segments, as shown in Fig. 215. In order that the method adopted

in obtaining the shape of the segment patterns may be clearly understood, it will be an advantage to first go carefully over the setting out of the pattern for an irregular article whose ends are circular, and not parallel. An elevation of such an article is shown in Fig. 214. This class of object gives good scope for illustrating the use of the method of triangulation in obtaining surface developments, and should, therefore, be taken particular notice of, as by this method any article whose surface is developable can have its pattern set out.

Imagine the circles that form the top and bottom of the article in Fig. 214 divided respectively into twelve equal parts, and that corresponding points be joined; then, on each quadrilateral so formed a diagonal drawn. It will thus be seen that the surface of the article would be divided into

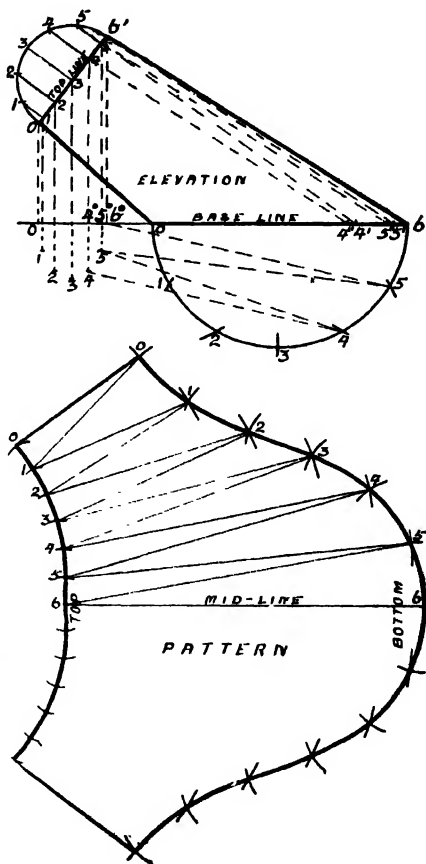


FIG 214.

twenty-four triangles. The pattern is then built up, as it were, by getting the true shape of each of these triangles and adding them together, as shown in the one half of the pattern in Fig. 214.

Let us now go over the construction. From the numbered points on the top line projectors are run down to, and across, the base line; their distance below this being cut off equal in length to the corresponding line on the top semicircle. Thus the dotted lines 4 4° and 5 5° will be respectively equal to the perpendiculars drawn through points 4 and 5 on the semicircle down to the top line, and so on for the other lines. If the points 0, 1, 2, etc., be joined up, it will be seen that the half-plan of top becomes a semi-ellipse. There is no need in practice to draw in the ellipse; all that is wanted being the plans of the points.

For the pattern the mid-line 6 6 is first laid down, being made equal in length to the line 6 6' from the elevation. Now, to obtain the true length of the diagonal for line 6 5 on the pattern, measure from 6° on the ellipse to 5 on the bottom semicircle, setting this distance along the base line from 6°, and so obtaining point 5'. The length of the dotted line 5' 6' from the elevation is now measured off and used as radius from point 6 at the top end of the pattern, and a small arc drawn (shown passing through 5 at the bottom end of the pattern). The compasses are now set to the length of one of the six arcs on the base semicircle, and with point 6 at the bottom end of the pattern as centre, a small arc is drawn to intersect the first arc, and thus fix the point 5. The dotted line 5 5 from the plan is now set along the base line from 5°, and the point 5'' marked. The line from 5'' on the base line to 5 on the top line is measured off, and used as a radius from point 5 at the bottom end of the pattern to describe the small arc passing through point 5 at the top end. This arc is cut by setting the compasses to a radius equal to the length of one of the six arcs

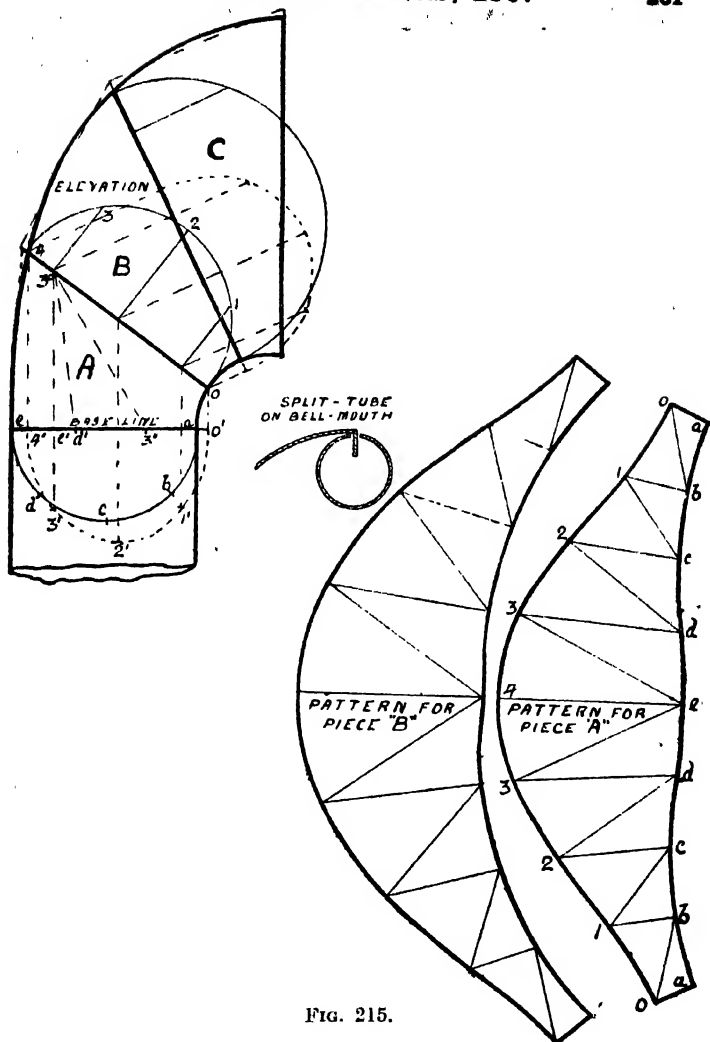


FIG. 215.

on the top semicircle, and using point 6 at the top of the pattern as centre. Thus point 5 at the top end of the pattern is determined. In the same way the lengths of all the other lines can be found. Thus 5<sup>o</sup> 4' on the base line equals 5 4 on the plan, and the line 5 4 on the pattern will equal the dotted line drawn from 4' on the base line to 5 on the top line; the distance 4<sup>o</sup> 4" will equal 4 4 on the plan, and line 4 4 on the pattern equals 4" 4 on the elevation, and so on for the remaining lines.

It is well to remember for practical purposes that there is no need to draw any of the dotted lines on the plan or elevation, or any of the construction lines on the pattern. All that is wanted being the fixed points, such as those obtained on the lower half of the pattern by the intersection of arcs.

The above method has been explained at some length, on account of its great importance. The reader should, therefore, find no difficulty in following its application to a

### Ventilator Head in Segments.

An elevation which illustrates this method of constructing a head is shown in Fig. 215; the body being divided into three segments, A, B, and C.

The patterns for two of the parts are shown set out, and after what has been said in connection with Fig. 214, it will be sufficient to briefly indicate the method of obtaining one pattern, say, for segment A. The back and throat curves are each divided into three equal parts, and the joint lines drawn. On these semicircles are described and divided into, say, four equal parts. Now to deal with the lines required for the pattern of segment A. From each of the division points of the semicircle, which is described on O 4, drop perpendiculars on to that line, and from the feet of these perpendiculars run lines down square to a e

and across it, cutting them off equal in length to the corresponding lines on the semicircle. There is no need to join the joints so found; but if they are connected together it will be seen that they form a semi-ellipse as in Fig. 214. The mid-line  $4\ e$  of the pattern will, of course, be made the same length as  $4\ e$  in the elevation. Now fix the compasses to  $e\ 3'$  and set this distance along the base line from  $e'$  and so determine the point  $3''$ . The line  $3''\ 3^0$  will give the required length of  $e\ 3$  for the pattern. Next measure  $d\ 3'$  and set this along the base line from  $e'$ , and so obtain the point  $d'$ . The line  $d'\ 3^0$  will then be the length required for the line  $d\ 3$  on the pattern. In the same manner the lengths of all the other lines required to construct the eight different triangles on the half-pattern can be obtained. The lengths  $e\ d$ ,  $4\ 3$ , etc., will be taken from the lengths of one of the parts on the respective semicircles, as in Fig. 214.

All the construction lines actually required to strike out the pattern for the piece B are shown on the elevation; but as the marking out is only a repetition of that already gone over for segment A, there is no need for any further description. The pattern for C is not shown; but this will, of course, come out in the same manner as for the other segments.

If the backs of each segment are to be left straight (which is sometimes done in very common heads), as in Fig. 214. then the patterns as laid out in Fig. 215 will be quite correct; but if they are to be hollowed to the required curve, then it will give a more accurate result to produce the joint lines out to the dotted lines of the backs, and describe the semicircles on these, thus making allowance for the drawing-in of the backs of the segments somewhat in hollowing.

As pointed out in connection with the pattern for Fig. 214, it should also be noted that there is no need to draw a single construction line on the pattern, all that is wanted

being the points obtained by the intersection of the arcs. The construction lines are simply shown to illustrate the principle of setting out the pattern.

No allowance for jointing has been made, as this can be added according to requirements.

The method of fixing the split-tube to form the bead around the mouth is also shown in an enlarged view on Fig. 215.

### Conical Ventilators, Etc.

The patterns for a ship's rib-head ventilator, instead of being set out by the method of triangulation, as just explained, can often be

more conveniently developed by treating each segment of the ventilator as part of a cone. Before describing how this can be done, however, it will be necessary to first explain how a cone and a cylindrical pipe can be made so as to fit together exactly. To do this it will perhaps be the best plan to go over the striking out of the patterns for a simple cowl made up in the way of a

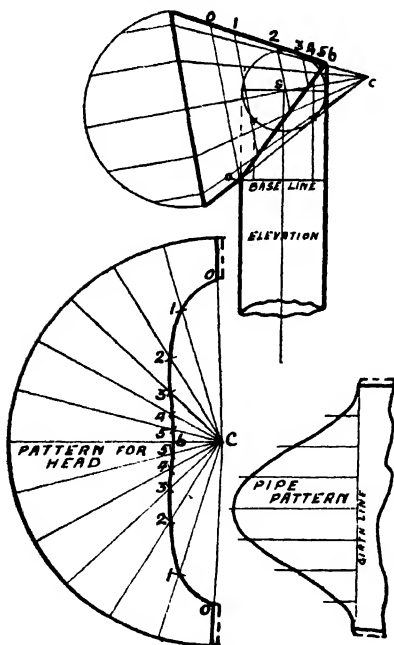


FIG. 216.

### Cone and Pipe Connection.

The most important thing to take notice of



in jointing together a cone and pipe is to so arrange them that the elliptic cut on the cone shall be exactly the same shape and size as the cut on the pipe. This is done by imagining that both cone and pipe are tangential to a common sphere. In practice it amounts simply to drawing in a circle, equal to the diameter of the pipe, and then fitting the cone so that its outside lines shall touch the circle. Thus, in Fig. 216 a circle is described from centre, *s*, having a radius equal to that of the pipe, and then drawing the pipe and cone to touch this in any position, as required. The points where the outside lines of cone and pipe intersect will give the ends, *a* and *b*, of the joint line. This construction should be most carefully gone over, on account of its great importance, it having to be used in all cases where conical and cylindrical pipes are required to be connected together in this way.

The pattern for the round pipe will be set out in the usual manner, lines above the base line being measured off to determine the length of those to the left of the girth line on the pattern.

The construction lines for the conical pattern will be obtained in the ordinary way by running radial lines, as shown, and from where these cross the joint line, *a b*, drawing lines square to the axis on to the outside of cone. After having set out the pattern for the complete cone the points, 0, 1, 2, etc., are obtained by cutting off the lines, C 0, C 1, etc., equal to *c* 0, *c* 1, *c* 2, etc., from the elevation.

No allowance for connecting pipe and cone is shown, this being put on according to the method of jointing followed.

### Ship's Rib-Head Ventilator.

An elevation of one form of this is shown in

Fig. 217, the head being made up in four pieces. So that each segment shall come out as a portion of a cone, it will be necessary to construct circles on the centre line, as shown by those described from centres  $n$ ,  $o$ , and  $p$ . The shape of segment A is formed by drawing a cone, apex  $a$ , to touch the sphere whose centre is at  $n$ . The joint lines for the parts B, C, and D are determined by drawing a

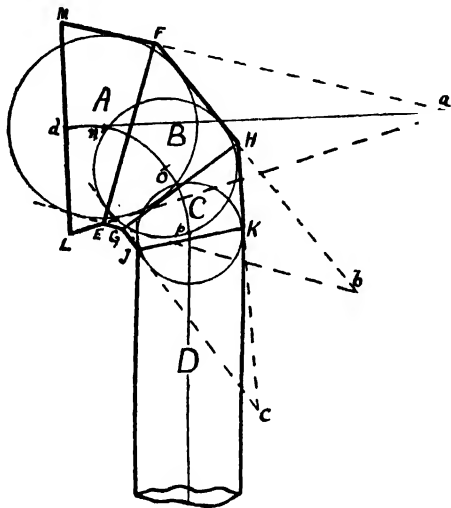


FIG. 217.

cone to touch spheres  $n$  and  $o$ ; a cone, apex  $c$ , to touch spheres  $o$  and  $p$ , and the pipe, D, to touch the sphere  $p$ . Where the outside lines of the respective pairs of cones intersect will give the ends of the joint lines. Thus E F is the intersection of cones whose apices are  $a$  and  $b$ , G H that of  $b$  and  $c$ , and J K the joint between cone  $c$  and the cylindrical pipe, D. To have a circular mouth; the line, L M, must be square to the cone axis,  $d a$ .

The back and throat of a ventilator may be curved as shown by the dotted lines in Fig. 218, and the shape of the segments still obtained in the same manner as above.

The pattern for one segment only—that of B—is shown set out in Fig. 218. The complete cone is first constructed by making  $bO$  equal to  $b4$ , and drawing in a base line,  $O4$ . Upon this base line a semicircle is drawn and divided into four parts. From each division point on the semicircle a perpendicular is dropped on to the diameter, and then radial lines run on to the apex  $b$ . Where these radial lines intersect the joint lines,  $4d$  and  $f e$ , lines square to the cone axis are run on to the outside of the cone. Thus, all the construction lines required for the pattern are determined. The complete cone pattern is first marked out in the usual way by taking  $bO$  as radius and stepping eight lengths, each equal to one of the arcs on the semicircle along the girth line. These points are now joined up to  $b$ , and the radial lines so drawn cut off by using the lengths already found on the side  $bO$  of the cone. Thus, to follow the fixing of one pattern point, the line  $33^0$  is drawn on the semicircle,  $3^0$  joined to  $b$ , and  $3'3''$  drawn parallel to the

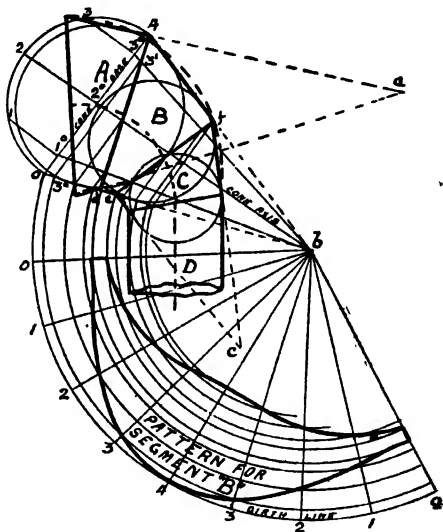


FIG. 218.

the fixing of one pattern point, the line  $33^0$  is drawn on the semicircle,  $3^0$  joined to  $b$ , and  $3'3''$  drawn parallel to the

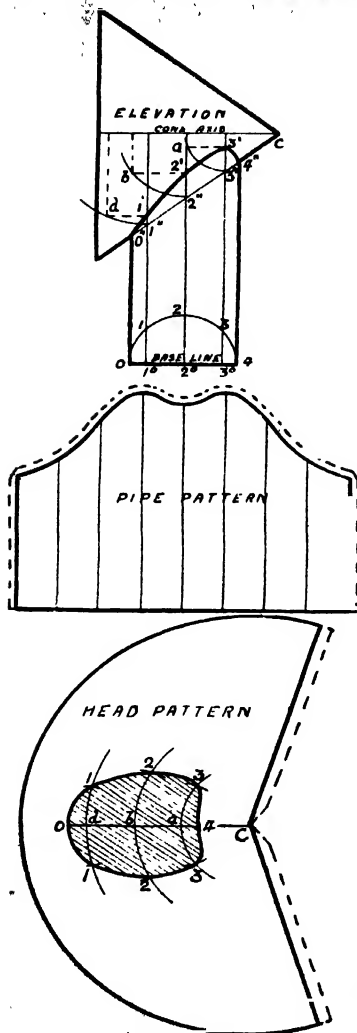


FIG. 219.

cone base, or square to the axis; the distance  $b\ 3''$  is then swung around on to the radial line,  $b\ 3$ , and in this way a point on the pattern curve is obtained. In a similar manner the other points can be determined.

The patterns for the segments A and C are not shown set out, as these, of course, can be developed in exactly the same way as explained above in connection with segment B. The pattern for the pipe D can be marked out as in an ordinary elbow, or similar to the straight pipe in Fig. 216.

A simple and cheap form of cowl can be designed by fitting a

### Round Pipe on Cone.

In this case, where the two centre lines are at right angles, the patterns come out in an easy manner. An elevation of such a cylindrical pipe and cone fitting together is shown in Fig. 219. So

that the construction lines for the patterns may be obtained, the usual method of drawing an elevation of the joint line must first be gone over. Describe a semicircle on the base line and divide it into four equal parts, running lines up through each division point to the cone axis, as shown. Now, from the points where these lines intersect the axis, draw the arcs 1" *d*, 2" *b*, and 3" *a*, of indefinite length. Then measure the lengths of the respective lines which are drawn across the semicircle, marking their distances along the cone axis, projecting down, and so obtaining the points *a b d*. Thus *d* 1' will be equal in length to 1 1° on the semicircle, *b* 2' equal to 2 2°, and the line *a* 3' equal to 3 3°. By running lines back through *a*, *b*, and *c* parallel to the cone axis, points on the joint curve will be determined.

The pattern for the cylindrical portion will be struck out, as before explained, by measuring off the construction lines between base line and joint curve.

The hole in the head pattern can be drawn by marking *C* 0 equal to *c* 0" on the elevation, and then describing the three arcs to the respective radii: *C d* equal to *c* 1", *C b* equal to *c* 2", and *C a* equal to *c* 3"; the point 4 being fixed by making *C* 4 equal to *c* 4". The lengths of the arcs, *d* 1", *b* 2", and *a* 3", on the elevation are then carefully measured, and their lengths set respectively along *d* 1, *b* 2, and *a* 3 on the pattern. The points found are then joined up, and so the shape of the hole obtained.

For stock patterns, or where a number have to be marked off the one pattern, a greater degree of accuracy will be ensured by having more construction lines, such as dividing the semicircle into six or eight parts, instead of four, as in the present example.

The dotted line on the top of the pipe pattern shows the necessary allowance for a flange for riveting on to the cone.

## Pipe on Cone Obliquely.

When the centre line of the pipe is inclined to that of the cone (Fig. 220), then the determining of the joint curve is a more difficult matter. The only real difference, however, between the construction in this problem and the last is in the arcs  $d\ 1''$ ,  $b\ 2''$ , and  $a\ 3''$ ; for whereas in the former case they were arcs of circles, in this example they come out as parts of ellipses. The difference of construction, then, lies in obtaining the shapes of the elliptic arcs. To do this all that is necessary is to first get the two diameters of the respective ellipses, and then set the small arcs

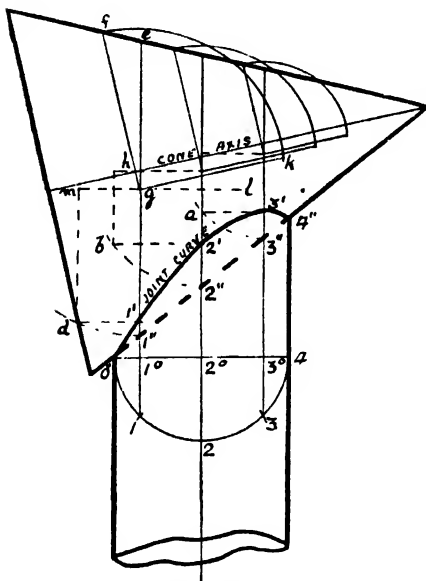


FIG. 220.

out by the method shown in connection with Fig. 213. It will perhaps be sufficient to explain how to get the diameters of the ellipse of which the arc  $d\ 1''$  is a part, as the method will be the same for each arc. Draw the line  $l\ e$  parallel to the centre line of the pipe, and bisect  $l\ e$  in  $g$ . Draw  $g\ f$  square to the axis of the cone, and on  $h\ f$  describe a quarter-circle, producing it a little beyond the point where it meets the cone axis. Now draw a

line through  $g$  parallel to the centre line of the cone, to meet the quarter-circle produced in  $k$ . Then the line  $g\ k$

will be half the small diameter, and the line  $g e$  half the large diameter of the ellipse. These two lengths are set along a trammel, as previously explained, and the two points slid along the lines  $g 1$  and  $g l$ , thus obtaining the curve  $d 1''$ . Now mark off  $g m$  equal to  $l^o 1$ , and draw a line down parallel to  $g 1$ , and so fix the point  $d$ . The line  $d 1'$  is then drawn square to  $d m$  or  $g 1$ , and thus the point  $1'$  on the joint curve is found. In the same way the other points  $2'$  and  $3'$ , can be determined.

The striking out of the patterns is not shown, as this part of the work will be done in an exactly similar manner to that illustrated by Fig. 219.

### Lobster-Back Cowl.

The construction of a lobster-back cowl (Fig. 221) follows somewhat similar lines to that of a quarter-bend, made up in segments, as shown in Chapter IV. In some cases where the throat part is curved the setting out of the patterns will be exactly the same as the quarter-bend; but in the present case, where the mouth and bottom pieces of the cowl meet, and are square to each other, some modification of the pattern is required.

A side elevation of the cowl, exhibiting the arrangement of the seg-

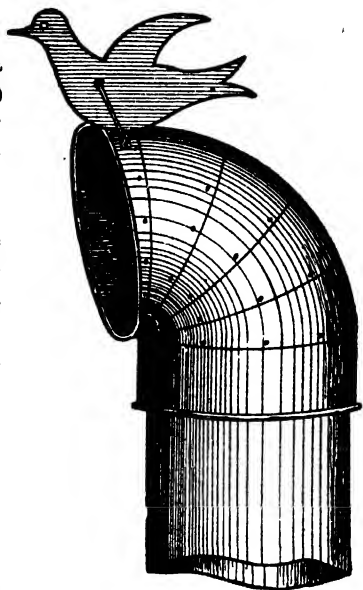
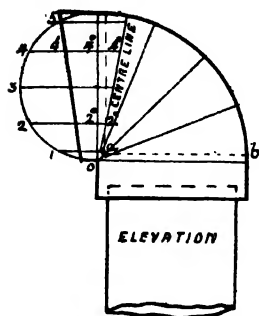


FIG 221.

ments, is shown in Fig. 222. The curved part of the back is formed of a quadrant of a circle, and is usually, as in this



case, divided into four equal segments. The mouth and bottom pieces are respectively produced in to the dotted lines *a b* and *a c*, being themselves connected along the line *o a*. The four back segments are thus, as it were, joined on to these.

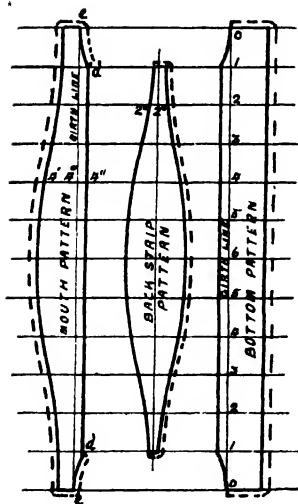


FIG. 222.

The construction lines for the mouthpiece are obtained by describing a semicircle on the line *o b*, dividing this into six equal parts, and running lines square to the diameter and across to the dotted line *a c*. The pattern is set out by first marking down the girth line equal in length to twelve times one of the small arcs on the semicircle, drawing lines square across, and cutting them off equal in length to the construction lines measured on either side of *o b* in the elevation. Thus, to show one line, the parts  $4' 4''$  and  $4' 4''$  on the pattern are equal to the same figured lines in the elevation.

The bottom pattern will be marked out in the same way as the mouth pattern, and it should be noticed that the ends of both of these are cut



away, so as to form the square throat, when bent and fixed in position. A small lap is allowed on to the end cuts, *d e*, of the mouth pattern, to cover for turning inside the bottom piece and riveting, if required.

The pattern for a back strip can be marked out from the same construction lines as previously used; but here the girth line will be shorter, being equal in length to ten only of the small arcs on the semicircle; this shortness being arranged so as to avoid all the strips meeting in a point under the throat. The width of the different parts of the pattern-strip will be measured from the line 0 6 in the elevation up to the centre line of the segment. Thus the distance 2° 2" on the pattern will be the same as 2° 2" on the elevation, and so for all corresponding lines. A lap will be allowed on one side of the strip, and also on both ends, so that they may be brought round and riveted on to either the mouth or bottom piece. Allowances have also been put on mouth and bottom pieces, to cover for wiring on the outer edges.

The wind-vane can be cut out any shape to suit the individual taste, a lug being left on the bottom to turn over and rivet on to the cowl-head.

In order that the head may revolve, a spindle is rigidly fixed along the centre of the pipe-shaft, which should fit into a centre on the head. This arrangement, however, is so well known that there is no need to give further details.

## CHAPTER XXVII.

## HOLLOWED ARTICLES.

To obtain the exact shape of a plate or sheet in the flat, for an article whose surface has a double curvature, is generally almost impossible. In practice, however, very good approximations can nearly always be found; the degree of accuracy in working up into the finished article depending more or less upon the treatment that the metal receives at the hands of the workman. In all good work, especially that which has to be under pressure, such as steampipes, the object aimed at should be to keep the plate in the finished article the same thickness all over, or, at any rate, to mind that it is not unduly thinned at any particular part.

As one workman will stretch or draw the plate more than another, it is obviously impossible in this class of work to set out a pattern that will suit all manipulators. Two things should be kept in view in marking out patterns for hollowed work—one is to make sure that the plate is not too small, and the other to mind not to waste metal. It is an easy matter to get a plate large enough, and then to shear and cut away in working up until the right size of object is obtained; but this manifestly is a most expensive method to follow, especially in the dearer metals such as brass and copper.

Generally, in hollow work, a good guide to follow is to try to set out the net pattern so as to have the same area as the surface of the finished article. After this, allowance can be made, if required, for any undue contraction or draw, and also for trimming and jointing.

## Spherical Bowl.

The simplest article of hollow work to obtain the pattern for is probably that of a bowl as seen in Fig. 223. The size of disc for this can be obtained in several ways, all based upon the assumption that the area of the circular pattern is equal to the area of the curved surface of the bowl. The above assumption is practically correct, and would be strictly so if the metal of the hollowed bowl were exactly the same thickness as the sheet from which it had been worked up. To keep the metal the same thickness is almost impossible in practice; but what area is lost by contraction is generally balanced by that gained in expansion.

If the bowl is in shape a hemisphere, then the radius of the disc can be calculated if we remember that "the area of the surface of a complete sphere is equal to the square of the diameter multiplied by 3.1416." That is, area of sphere surface =  $d^2 \pi$ , and as the area of the disc must be equal to half of the above, we have—

$$R^2 \quad \frac{d^2 \pi}{2} \therefore R^2 = \frac{d^2}{2}$$

and—

$$R = \frac{d}{\sqrt{2}} = \frac{d}{1.4}$$

where R equals radius of pattern disc. This gives us a handy rule, for in all cases where the bowl is half a sphere, the radius of the circular pattern will be found by dividing the diameter of the sphere by 1.4.

For those who are not good at calculating the same result can be

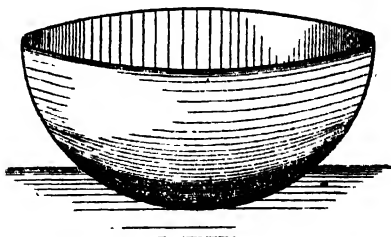


FIG 223.

obtained graphically by aid of the construction shown in Fig. 224. This construction, indeed, may be taken generally and applied to all hollowed work that comes out as any segmental portion of a sphere. Essentially the construction consists in setting out a right-angle triangle, one side

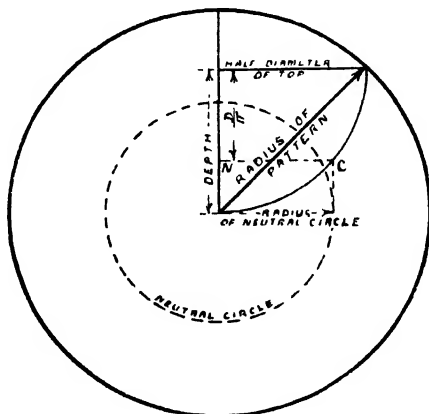


FIG. 224.

being equal to half the diameter of bowl, and the other equal to the depth; the hypotenuse or third side then giving the radius of the disc.

The general case is perhaps better explained by Fig. 225, the parallel lines representing the top of bowls, and the dotted lines with the numbered  $R$  giving the radius of the corresponding required disc. Thus the line  $R^1$  will give the radius of a circular plate which will work up to a bowl whose top is represented by the line 1 1. In the same way a circular plate whose radius is equal to  $R^3$  would form a bowl whose diameter at top would be equal to 3 3.

From Fig. 225 it is interesting to observe that the radius of a circle having the same area as a sphere will be equal to the diameter of the sphere. So that, if it were possible to work a sheet metal disc into a complete ball of the same

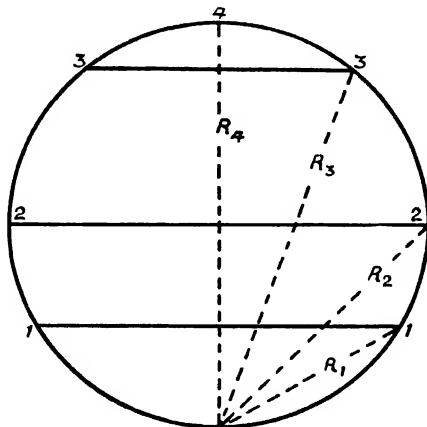


FIG. 225.

thickness metal, the diameter of the disc would be just twice that of the sphere.

In calculating the surface area of a sphere, or any part of a spherical surface, it is often handy to call to mind the relation that exists between the surfaces of the sphere and cylinder. "The area of a sphere, or the curved surface of a segment or zone of a sphere, is equal to that of the circumscribing cylinder or part of cylinder." Thus, in Fig. 226, the area of the segment of sphere  $A B C$  will be equal to the area of the curved surface of the part of cylinder  $a c b b$ , which is cut off by  $A C$ , produced as shown. In the same way the area of the curved surface of zone will equal the part of cylinder cut away by producing  $D E$  and  $F G$ .

This somewhat peculiar property of the sphere and cylinder occasionally comes in handy in setting out patterns for plumber's and coppersmith's work, and also in estimating weights of sheet metal required in work of this character. It is also of use when the end of a straight pipe is required to be worked to form part of a dome end, such as in coppers, steam-dome covers, and coal-scoops. Referring again to Fig. 226, suppose we require to work the end of a straight pipe into the shape  $b H F$ , or  $b L G$ , then the length of pipe wanted to form the domical part  $H F$

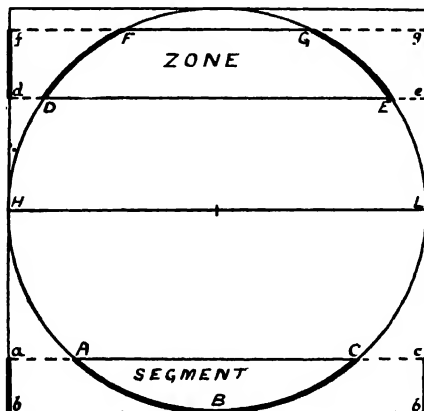


FIG. 226.

would be  $H f$ . It should be borne in mind that if the point  $f$  is to be worked around to  $F$  it will be necessary in the raising to so stretch the metal as to keep it a constant thickness.

### Raising a Bowl.

In working up a bowl or any similar article or part of an article, the sheet may be either "raised" or "hollowed." The raising process is more particularly suitable to the

softer metals, such as lead, pewter, copper, and brass, and is carried out, as shown in Fig. 227, the sheet metal being drawn over the head by working round course after course. The edges of the sheet will wrinkle a good deal, and particular care must be taken, especially in thin metal, that the sheet does not double over, or else the job will be ready for the scrap-heap. To avoid this, work around the bowl

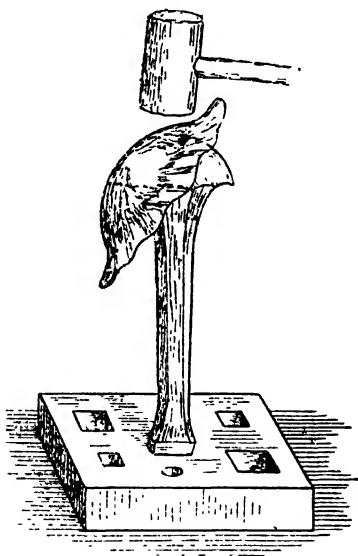


FIG. 227.

gently, and if unduly large wrinkles appear, work them out carefully to the edge of plate. If the job is of copper or brass, it should be annealed two or three times during the working up.

To obtain a smooth surface and to harden and stiffen the

metal the job should be finished off with the hammer. The planishing being done with a round flat or concave-faced hammer on a smooth bullet-head stake, as shown in Fig. 228. The blows should be carefully placed, commencing at the centre and gradually working out to the edge. The surface should not be struck twice in one place; but the hammer-marks should join on to each other. The greatest care must be taken that the sharp edge of the

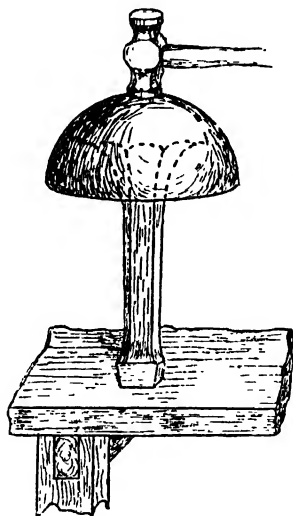


FIG 228.

hammer-face does not strike the surface, as it is almost impossible to obliterate marks of this character, and if left on, the appearance of the article is not by any means improved.

If the surface is to be polished it should be observed that it is free from scale and perfectly clean before the planishing takes place, as every particle of dirt on the surface will



be driven into the metal by the hammering, and will be most difficult to remove in the polishing.

### Hollowing a Bowl.

In hollowing, the sheet metal is hammered into a recess in either a block of wood, cast iron, or lead. For general work it is most convenient to have a wooden hollowing block as shown in Fig. 229. Recesses can then be readily sunk into the ends to suit the shape of the work in hand. A bullet-faced hollowing hammer is used, the sheet being first wrinkled around the edge, and the courses following each other up to the centre of the plate. The plate should not be hammered too much at the middle whilst the edges are stiff, as this will tend to unduly stretch, and thus thin, the metal at that part.

"Hollowing" is usually a much quicker process than "raising," but it has a tendency to thin the sheet in the middle part more than the latter method. The stiffer metals, such as steel, iron, and zinc, are generally treated by the former process.

### Wrinkling Circle.

Whether the hemispherical bowl is raised or hollowed, it will be observed that the centre portion of the disc is stretched, whilst that part which is nearer to the edges will contract; there must, therefore, be a part of the disc or bowl which is neutral;

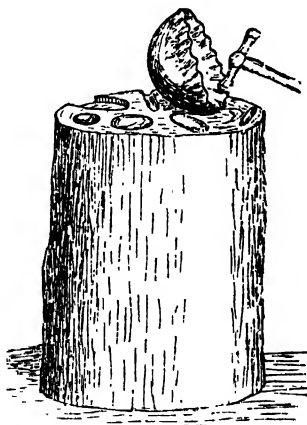


FIG 229.

that is, neither stretches nor contracts. This will be a circle lying on the surface of the bowl, and shown by the line N C in Fig. 224. To determine the position of this circle, a distance equal to the diameter of the hemisphere divided by 3.1416 is set down from the top, and a line parallel to the top of bowl then drawn; this gives the diameter of the neutral circle. Taking a hemispherical bowl of 5 in. diameter, the distance down of the neutral circle will be—

$$\frac{d}{\pi} = \frac{5}{3.1416} = 1.6 \text{ in.}$$

In the working up, this circle should remain of constant diameter, and therefore gives us the boundary line where the wrinkles from the edge of disc should die away. In

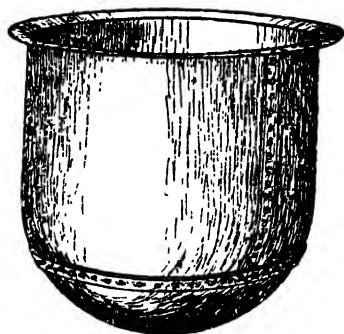


FIG. 230.

copper bottoms, and such like work, the wrinkling circle should be marked on the circular plate, and the wrinkles put in on the outside of this circle.

### Patterns for Copper.

The setting out of the patterns for a copper (Fig. 230) conveniently comes in with our consideration of the sphere.



flat end, it can be made to carry various heads and do similar work to the horse in a floor-block.)

The stretching or throwing off of the brim is explained by Fig. 233. This can either be done on a head stake as shown, on an anvil, or on the edge of the flat end of bench bar. In stretching the brim the depth of flange should first be marked around the inside. When throwing the brim off on the stake, care should be taken that the more intense part of the hammer-blow falls near the edge of metal, as the greatest amount of stretch must, of course, take place on the outside of the brim.

The position of the wrinkling circle for the bottom, and

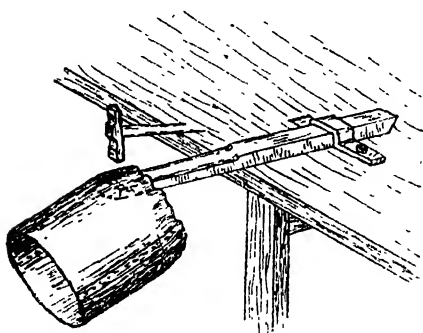


FIG. 232.

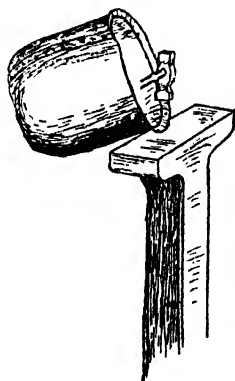


FIG 233.

thus its diameter (Fig. 231) can be determined by the following rule: "To find the distance of the neutral circle from the bottom, deduct the chord from the arc, and multiply this difference by the radius and divide the product by the arc." That is—

$$CN = \frac{\text{radius } OD \times (\text{arc } ACD - \text{chord } AD)}{\text{arc } ACT}$$

Before proceeding to completely rivet up, the bottom should be attached with a few tacking rivets. In finishing the joints care should be taken that the seams are properly countersunk, and also that the tails of rivets are drawn up, so that the inside of the copper shall be completely smooth.

Sketches of hammers are shown in Fig. 234, the two on the left being types of hollowing or blocking hammers, the centre one a stretching or razing hammer, and the right-hand

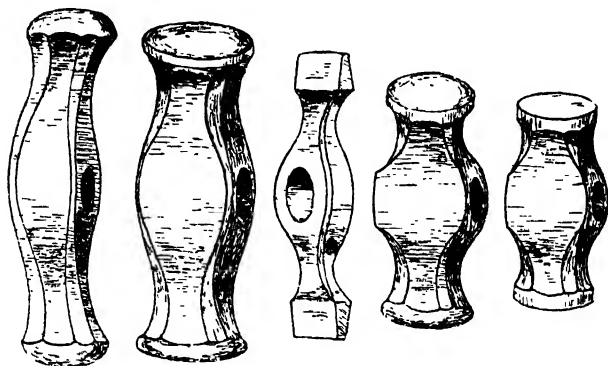


FIG 234.

pair planishing hammers. It is, perhaps, hardly necessary to point out that there are hundreds of different shapes and sizes of the above, the form of hammer used depending upon the strength of material and kind of job in hand.

### Capacity of a Copper.

Before proceeding to show how to calculate the number of gallons that a copper of the shape shown in Fig. 230 will hold, it will be necessary to explain how to find the volume of a sphere.

One of the simplest aids to the remembering of how to find the volume of a sphere is in the peculiar relation that exists between the volumes of a cone, sphere, and cylinder when their diameters and heights are equal. Imagine that Fig. 235 represents these three solids, then the relative volumes of cone, sphere, and cylinder will be as 1 is to 2 is to 3. So that, having found the volume of the cylinder, the sphere will be two-thirds, and the cone one-third of it. It will also be seen that the sphere is just twice the volume

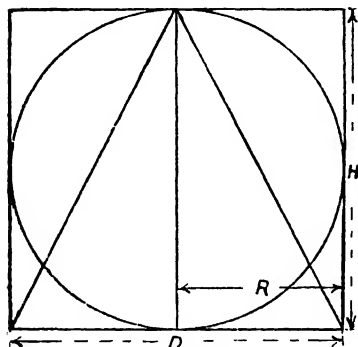


FIG 235.

of the cone. The above relation facilitates the work in calculating the cubic contents of a vessel with hemispherical or conical ends.

If a vessel has hemispherical ends, all that is necessary is to add two-thirds of the diameter on to the cylindrical portion, and calculate its volume.

If a vessel has a conical bottom or top pointing outwards, then its volume can be found by adding one-third the height of the cone on to the cylindrical portion, and calculating as before. If a vessel has a conical bottom pointing inwards, then, of course, one-third the height of cone would be deducted from the length.

It is sometimes convenient to use the ordinary mensuration rules, such as—

Volume of sphere—

$$= \frac{\pi d^3}{6} \quad \pi 4 r^3 \quad r^3 \times 4.1888$$

Volume of cone—

$$= \frac{\pi d^2 h}{12} = \frac{\pi r^2 h}{3} = r^2 h \times 1.0472$$

Volume of cylinder—

$$= \frac{\pi d^2 h}{4} = \pi r^2 h = r^2 h \times 3.1416$$

Where  $d$  = diameter,  $r$  = radius, and  $h$  = height.

In practice, it is handier to use some such rules as the following, which have been calculated on the basis of 277.274 c. in. to the gallon. Taking dimensions in feet—

$$\begin{aligned} \text{Gallons in cylinder} &= r^2 h \times 19.6 \\ \text{,, sphere} &= r^3 \times 26.11 \\ \text{,, cone} &= r^2 h \times 6.53 \end{aligned}$$

If the dimensions are in inches, then the following multipliers must be used—

$$\begin{aligned} \text{Gallons in cylinder} &= r^2 h \times .01133 \\ \text{,, sphere} &= r^3 \times .01511 \\ \text{,, cone} &= r^2 h \times .00378 \end{aligned}$$

Taking one example to illustrate their use. Suppose we require to find the number of gallons in a hemispherical bowl of 20 in. diameter. Then—

$$\text{Gallons} = \frac{10 \times 10 \times 10 \times .01511}{2} = 7.55 = 7\frac{1}{2} \text{ (nearly).}$$

After the above explanation, let us come back to the copper. Suppose it is 3 ft. diameter and 3 ft. 6 in. deep. Then deducting half the diameter from the depth, this will give us 2 ft. for the length of the cylindrical part. Adding two-thirds the depth of the hemispherical bottom on to the cylindrical portion, this will give us an equivalent cylinder of 3 ft. length. The cubical contents will, therefore, be—

$$\frac{3}{2} \times \frac{3}{2} \times 3 \times 19.6 = 132.3 = 132\frac{1}{4} \text{ gallons.}$$

## CHAPTER XXVIII.

## SOLID PANS, JUGS, EXPANSION BULBS, ETC.

## Solid Round Pan.

A CIRCULAR pan or vessel, such as that shown in Fig. 236, can be raised or drawn out of the solid plate when such malleable metals as copper, brass, etc., are used. Articles of this description, when required in quantities, are drawn

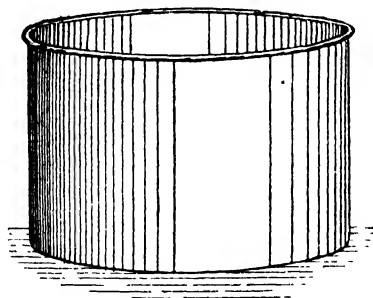


FIG 236

up out of blank discs, in two or three operations, by the aid of suitable dies in a hand or power press. When a few articles only are wanted, they are formed by hand, the disc being gradually worked over a bench-stake, by the use of mallet and hammer, until the required shape is obtained. Whether

shaped by hand or machine, nearly all metals require annealing between each or every other operation.

In calculating the size of disc the thing to be kept in mind is to have a circular blank of the same area as the combined area of the bottom and sides of the vessel. This can be calculated or found by graphic construction. We will show both methods. For calculating the radius of the disc, the following rule can be used: "Add the square of the



radius of the pan bottom to twice the product of the radius and the depth, and extract the square root of the whole." Thus, in Fig. 237, suppose the diameter of the vessel is 2 ft., and its depth 1 ft. 6 in.; then the radius of the flat disc will be—

$$R \quad \sqrt{r^2 + 2rd} = \sqrt{144 + 24 \times 18} = \sqrt{576} = 24 \text{ in.}$$

A much simpler method, for those not good at calculations, is shown by the construction in Fig. 237. A B is the diameter of the circular pan, C the centre of the bottom, and B D the depth. Make B E equal to B D by turning the latter line down, as shown. Now describe a semicircle on A E, centre O, and produce B D to meet the semicircle in F. Join C to F, and the line C F will give the length of the radius for the blank disc. This latter method, it should be noted, will give the same result as obtained by calculation, the construction simply being a graphical method for working out the arithmetical problem as above.

In raising up the vessel care must be taken to keep the metal at as uniform a thickness as possible. If any trimming is required to be done, or wiring put on, then a

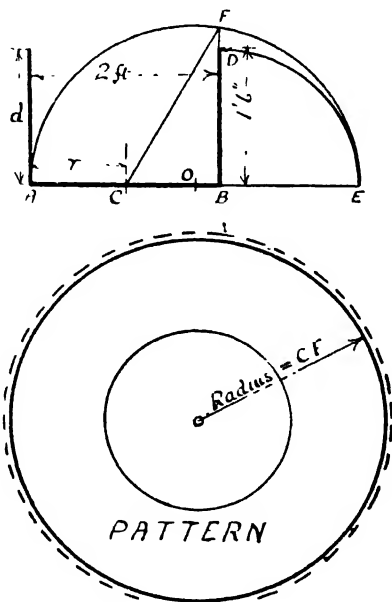


FIG. 237

small allowance should be added to the circular plate, as shown by the outside dotted circle.

### Solid Round-Tapered Pan.

If the size of the disc is required for working up into a circular pan, having a flat bottom and tapered sides, then, with some little modification, the rules, as used in the former case, can be applied. First of all, the mean radius of the pan must be found, and this is done by adding the radius of the bottom to the radius of the top and then dividing by two. The rule for finding the radius of the blank will then read as follows: "Add the square of the bottom radius to twice the product of the mean radius and the slant depth, and extract the square root of the whole." Suppose a pan of this description (Fig. 238) is 2 ft. 6 in. in diameter at the top, 1 ft. 6 in. at the bottom, and 1 ft. 3 in. slant depth.

- Let  $R$  = radius of disc.  
 „  $r$  = mean radius of pan.  
 „  $r_1$  = radius of bottom.  
 „  $r_2$  = radius of top.  
 „  $s$  = depth of slant side.

Then the mean radius will be—

$$r = \frac{r_1 + r_2}{2} = \frac{15 + 9}{2} = 12 \text{ in.}$$

The radius of the pattern disc will equal—

$$R = \sqrt{r_1^2 + 2rs} = \sqrt{81 + 24 \times 15} = \sqrt{441} = 21 \text{ in.}$$

The same result can be obtained graphically by the construction shown in Fig. 238. Bisect  $E F$ , and draw the line  $G H$  through the bisecting point parallel to  $A B$ . Draw  $H J$  parallel to  $C A$ , and thus cut off  $A J$  equal to

G H. Using A as centre, and A C as radius, turn A C down, and thus fix the point K. On K J describe a semi-circle, and draw the line A L square to A B to meet it. The length of the line drawn from L to F, the centre of the

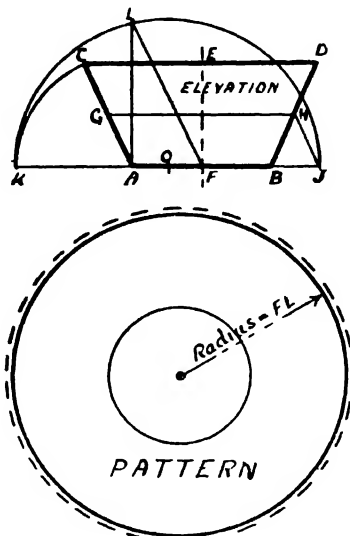


FIG. 238.

bottom, will give the radius for the blank disc. Any allowance required must, of course, be added on to the pattern, as in the last case.

### Vessels with Double-Curved Surfaces.

The patterns for articles whose surfaces are of double curvature can be marked out very approximately by an adaption of the methods already explained. Before, how-

ever, the methods can be applied to this class of object, it will be necessary to give some preliminary explanation. Suppose it is required to get the size of a circular blank that will work up into a

### Barrel-Shaped Vessel,

as shown by the section in Fig. 239. It should be remembered, as has already been stated, that the area of the pattern disc must be equal to the area of the bottom and

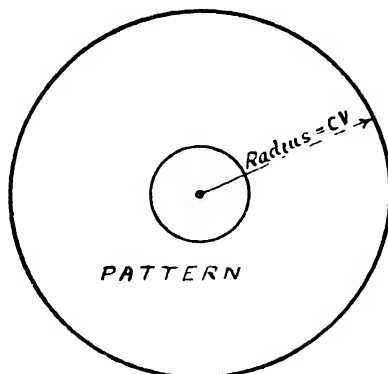
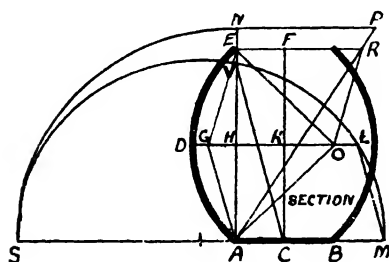


FIG. 239.

body together of the vessel. The bottom being a circle, there will, of course, be no difficulty in finding its area. To calculate the area of the body-surface, however, is a more difficult task. We may consider the body as being a surface of revolution—that is, a surface swept out by the arc A D E moving at a constant distance from the centre line C F. It is manifest that if the arc revolves in this manner, the surface generated would be that as shown by the figure. Now, the area of a surface formed in this way is equal to the length of the generating

curve—in this case the arc—multiplied by the distance that its centre of gravity would travel in one complete revolution. The centre of gravity, it may be explained, can be looked upon as an imaginary point upon which the section curve would balance in any position. For an arc of a circle, the position of its centre of gravity can be calculated by the following rule: "Multiply the radius by the length of the chord, and divide by the length of the arc; the result giving the distance of the centre of gravity from the centre about which the arc has been described."

For the benefit of those readers who can manipulate figures, we will now explain how to obtain the radius of the pattern disc by calculation, and then afterwards show how the same result can be found by construction. The arc A D E, in Fig. 239, which is described from the centre, O, is a quarter of a circle, of radius  $7\frac{1}{2}$  in.; hence its length will be—

$$\frac{15 \times 3\,1416}{4} = 11.78 \text{ in.}$$

The length of the chord A E will be—

$$\sqrt{2 \times (7.5)^2} = 10.6 \text{ in.}$$

The distance O G, from the rule stated above, will then be—

$$\begin{aligned} \text{O G} &= \frac{\text{Radius} \times \text{chord}}{\text{arc}} \\ &= \frac{7.5 \times 10.6}{11.78} = 6.75 \text{ in.} \end{aligned}$$

The distance of the centre of gravity, G, from the centre line C F will equal—

$$\text{O G} - \text{O H} + \text{A C.}$$

The diameter A B = 5 in., and in this case O H = H E = 5.3 in.; hence—

$$\text{K G} = 6.75 - 5.3 + 2.5 = 3.95 \text{ in.}$$

Having obtained the distance of the centre of gravity from the centre line, the radius of the pattern disc can now be calculated, as in connection with Fig. 238.

Let  $l$  = length of arc.

„  $r_1$  = radius of bottom.

„  $r$  = distance of centre of gravity from centre line.

Then—

$$R = \sqrt{r_1^2 + 2rl} = \sqrt{(2.5)^2 + 7.9 \times 11.78} \\ = \sqrt{99.3} = 10 \text{ in. (nearly).}$$

Whilst, perhaps, somewhat uninteresting, the calculations, as explained above, are very important, and have wide application in finding the areas of surfaces of this character. They can also be applied to finding the capacity or cubic contents of vessels such as those shown in Figs. 239, 240, and 245.

### Capacity of Barrel-Shaped Vessel.

Seeing that we have the dimensions in connection with Fig. 239, it will, perhaps, be better to explain how to find its volume before passing on. It should be remembered that whilst the calculations that follow apply to the vessel in Fig. 239, the same principle is applicable to all circular articles.

The distance of the centre of gravity of the segment A D E H A from O will equal—

$$\frac{\text{The cube of the chord}}{12 \text{ times area of segment}} \\ = \frac{10.6 \times 10.6 \times 10.6}{(11.78 \times 3.75 - 5.3 \times 5.3) \times 12} = 6.17 \text{ in.}$$

Distance of centre of gravity of segment from centre line equals—

$$6.17 - 5.3 + 2.5 = 3.37 \text{ in.}$$

Then the volume of the vessel equals the volume of the centre cylindrical portion, together with the volume swept out by the segment revolving around the centre line—

$$\begin{aligned}\text{Volume} &= (2.5)^2 \times 3.1416 \times 10.6 \\ ,, &+ 2 \times 3.37 \times 3.1416 \times 16.09 \\ ,, &= 208.03 + 344.59 \\ ,, &= 552.62 \text{ cubic inches.}\end{aligned}$$

To find the number of gallons the above would have to be divided by 277.274 (the number of cubic inches in a gallon). It will thus be seen that the vessel will hold just under two gallons.

#### **Pattern for Barrel-Shaped Vessel by Construction.**

To find the radius of the pattern disc, graphically, the line A N (Fig. 239) is made equal to the length of the arc A D E, and N P drawn square to it and equal to the radius O E. Line E R is then drawn parallel to N P, and the point R cut off by joining P to A. O G is then made equal to E R by joining R to O and drawing E G parallel to R O. The line K L is cut off equal to K G and L M drawn parallel to G A. Now, using A as centre, and A N as radius, the point S is marked off. A semicircle is next described on S M intersecting the line A N in V. The line C V is the length required for the radius of the pattern disc; and this, on measurement, will be found to be 10 in., as calculated before.

#### **Circular Pan with Sides Curved Outwards.**

The method shown above will apply to all kinds of different-shaped circular vessels, the only difference being in the finding of the centre of gravity of the side section. Perhaps one further example in the way of a pan with its sides curved outwards will make the construction followed plainer.

In Fig. 240 a section showing the shape of the pan is given. The line  $A N$  is cut off equal to the length of the arc  $A D E$  and  $N P$  drawn square to it, and made equal to the radius  $O A$ . The line  $A F$ , as shown, is marked off equal to the chord  $A E$ , and  $F R$  drawn parallel to  $N P$ , the point  $R$  being determined by joining  $P$  to  $A$ . Then the point  $G$ , which is the centre of gravity of the arc  $A D E$ ,

is fixed by making  $O G$  equal to  $F R$ . The point  $L$ , which is the corresponding centre of gravity for the right-hand arc, is found by drawing  $G L$  parallel to  $A B$  and making  $K L$  equal to  $K G$ .  $G$  is next joined to  $A$  and the lines  $L M$  drawn parallel to  $G A$ . After  $S$  has been determined by making  $A S$  equal to  $A N$ , a semi-circle is described upon  $S M$ , so fixing the point  $V$  on the line  $A N$  produced. The length of the line  $C V$  will give the radius for the disc.

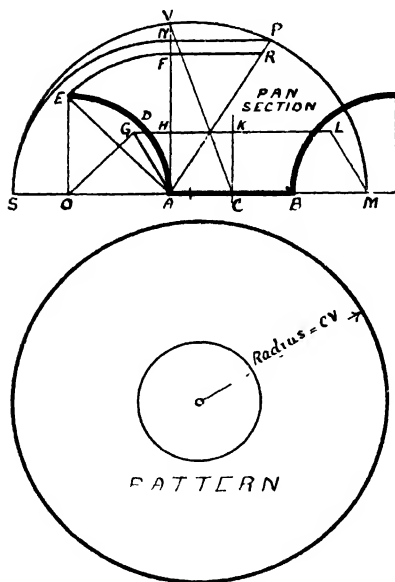


FIG. 240.

### Copper Expansion Bulb.

A copper expansion bulb, or ball, as shown in Fig. 241, is sometimes fixed upon a length of steam or hot-water pipe, to allow for the varying length of the pipe due to



changes of temperature. It is usually worked up from two circular discs of metal, the halves being fastened together with a brazed joint running around the bulb.

The setting out for the pattern disc is shown in Fig. 242. It is only necessary to mark out a quarter of the section shape, and then on this apply the construction used in Figs. 239 and 240. The point G can be taken as the centre of gravity of the curve (this being the point upon which a wire bent into the shape B G A would balance). A is joined to G, and produced to D, the line A D being made equal to the length of the double curve A G B. The line G F is next drawn parallel to A L and O F cut off equal to O G. The point H is then fixed by drawing F H parallel to G A. Line A D is turned up about A as centre to fix the point E, and on H E a semicircle described, cutting L J produced in K. The line A K gives the radius for the circular blank. After each half is worked up into the required shape, the centre circles are cut out to form the pipe inlet and outlet.

We will now give a couple of examples of the application of the foregoing methods to the setting out of patterns for articles which can be worked up from a frustum of a cone. The first example is that of a

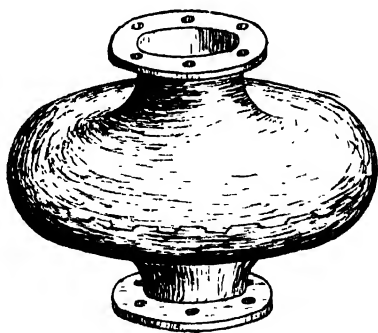


FIG 241.

### Steam Exhaust-Pipe Bell-Mouth,

as shown in Fig. 243. A heavy bead is worked on the pipe at the part where the bell-mouth runs into the straight

pipe, and a split tube is fitted around the top edge of the outlet.

The setting out for the pattern is shown in Fig. 244. The bead is first of all allowed for by lengthening the pipes by the distance  $A B$ , which is equal to the length  $C D E$  measured around the bead. The position of the point  $G$  is found by the rule explained in connection with Fig. 239.

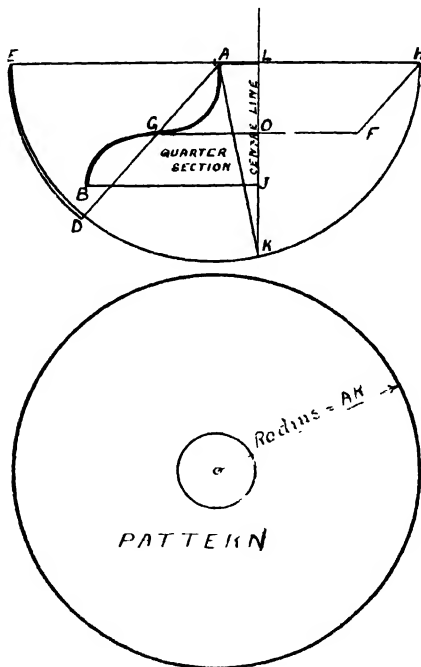


FIG. 242.

$F$  is the middle point of  $B E$ . The points  $G$  and  $F$  are joined together and the length  $G J$  made equal to  $F B$ ; then  $F H$  is drawn parallel to  $G J$  and made the same length as

the arc K L. Now, if H be joined to J, the point W, where it intersects the line F G, will give the centre of gravity of the section shape. The line N M is now drawn in an average position, its length being marked off equal to the outline B K L O. M N is then produced to meet the centre line in T. The pattern is now laid out as that for a

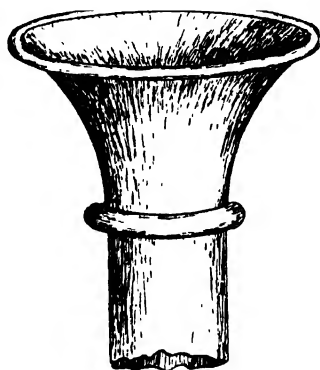


FIG 243.

cone frustum, the lengths T M and T N being used as the radii, and the length of the arc R S P being made equal to four times the length of the quarter-circle on V M.

### Copper Jug.

The second example is that of a jug, as shown in Fig. 245. The jug is made in four parts—the body, bottom, spout, and handle. The setting out of the patterns is shown in Fig. 246. A half-elevation, showing the spout portion, is first drawn. The line B D is marked in an average position on the outline, and the middle point C determined by drawing the line A C square to, and from the middle of the

centre line. B D is made equal to the length of the double curve E F H, the body pattern then being struck out, as in Fig. 244.

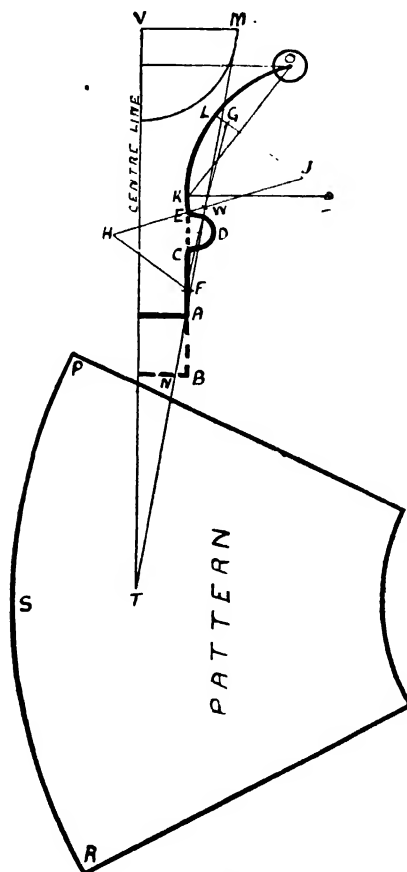


FIG. 244.

The inner circle on the bottom pattern is the same dia-

meter as the jug bottom, and for the outer circle the depth of the foot is added all round.

For the spout the half-section 0 1 2 3 is first marked out, this being divided up, as shown, and perpendiculars dropped on to the line H 3. Then, using centre P, the arcs *a b*, *c d* are swept around. The girth line 0' 0' on the pattern is made the same length each side its centre point as the



FIG. 245.

curve 0 to 3 on the spout. Construction lines are drawn through each division point, and these cut off, above and below the girth line, the same length as the arcs on the spout in elevation. Thus,  $a' b' = a b$ ,  $c' d' = c d$ , and  $e' f' = e f$ , the parts, of course, being measured above and below the line H 3. The points obtained are connected up with curves, and so the pattern completed.

The hole for the spout will be cut in the body after it has been worked into shape. The handle can be made in the form of a tapered tube, loaded with lead, and bent into

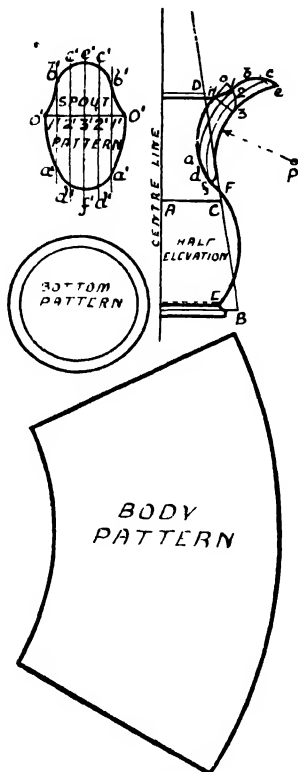


FIG 246.

shape; or it can be formed out of a bar of solid copper. It may be attached to the body by riveting.

The seam on the body can be brazed down to form the cone frustum.

After the body and bottom have been tinned on the

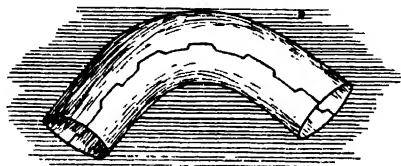


FIG. 247.

inside, the latter can be fixed in the former by soldering around the inside.

The surface of the jug may be polished and lacquered, or treated in any other way as desired.

## CHAPTER XXIX.

### WORKED-UP PIPE BENDS, BREECHES PIECES, ETC.

#### Pipe Bends.

SOLID drawn pipes, both of steel and copper, of diameters up to 6 in. or 7 in., can now by the aid of hydraulic or other bending machines be bent to form bends of various shapes, so that simple pipe bends made up out of sheet metal and brazed or riveted are not so common as formerly. Bends for pipes of large diameter, however, have to be made up, and also those for small pipes where no facilities exist for pipe bending. We shall, therefore, now consider a few typical cases of bends, tee-pieces, etc.

#### Quarter-Bend.

A quarter, or square, bend is usually made up in two pieces, the joints running along the back and throat, or along the two sides, as shown in Fig. 247. This latter method has several advantages over the former, one being that there is less waste in cutting out the plates, another that they are perhaps a little easier to shape, and a third the greater convenience in brazing side seams.

A method for obtaining the size of the plate is illustrated by Fig. 248. The exact shape of the quarter-bend is marked out as shown in the figure, and the joint line drawn in. Now before setting out the plates it will be as well to consider what happens when a plate is bent to form either the back or throat portion of the pipe. Consider the back



piece first. As the plate is brought into shape by hollowing and razing, it will be observed that the back of the half-pipe stretches and thus becomes longer, whilst the edge of the plate, which will form the joint, contracts, and thus becomes shorter. There must, therefore, be some line on the plate which neither gets longer nor shorter, and if we can obtain the length of this line, it will give us the length of the plate for back. The same reasoning also applies to the saddle or throat part of the bend; for, whilst the edges of the plate which form the joint line get longer in the working, the throat draws in, and thus the throat line becomes shorter. There must, therefore, also be a line on the saddle which remains of constant length. The posi-

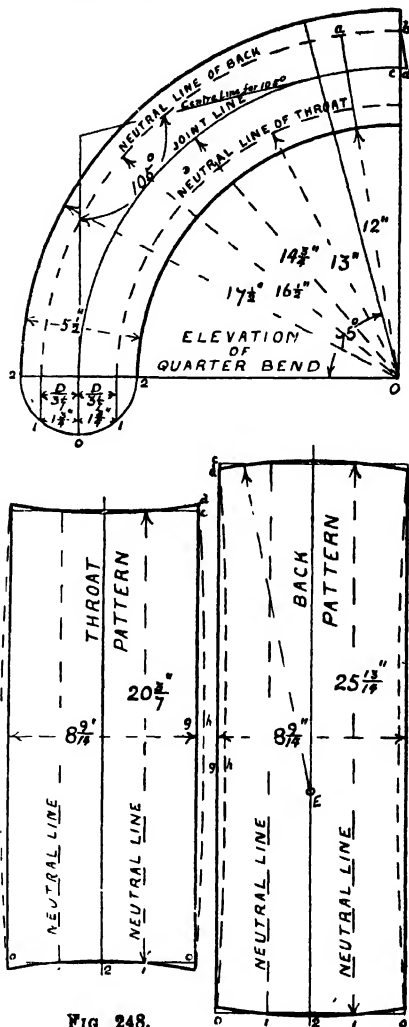


FIG 248.

tion of this neutral line on the back and throat pieces can be obtained from the following rule:—

“Divide the diameter of the pipe by  $3\frac{1}{7}$ , and set this distance on each side of the joint.” Thus, in the present case, the diameter of the pipe being  $5\frac{1}{2}$  in., the distance of the neutral line from the centre line of pipe will be—

$$\frac{D}{3\frac{1}{7}} = \frac{D \times 7}{22} = \frac{52 \times 7}{22} = 1\frac{3}{4} \text{ in.}$$

This distance is set on each side of the joint line, and the neutral line drawn as shown in Fig. 248. The size of the plates then will be obtained by making their widths equal to half the circumference of the pipe, and their lengths equal to the lengths of the respective neutral lines. The widths of the patterns will be—

$$\frac{5\frac{1}{2} \times 3\frac{1}{7}}{2} = 8\frac{9}{14} \text{ in.}$$

The length of the back piece—

$$\frac{16\frac{1}{2} \times 2 \times 3\frac{1}{7}}{4} = 25\frac{13}{14} \text{ in.}$$

and the length of the throat piece—

$$\frac{13 \times 2 \times 3\frac{1}{7}}{4} = 20\frac{3}{7} \text{ in.}$$

A somewhat peculiar fact should be noticed in connection with the lengths of the neutral lines, and that is, that the neutral line of the back is always, for a quarter-bend, exactly the diameter of the pipe longer than the neutral line of the throat. So that when the length of one line is determined the other can be obtained by adding or deducting the diameter of the pipe, as the case may be. In the present example we have—

$$25\frac{13}{14} - 20\frac{3}{7} = 5\frac{1}{2} \text{ in. (diameter of pipe).}$$

If there is any straight pipe on the end of the quarter-bend, then the length of this should be added on to the calculated length, and the ends of the pattern will be straight lines drawn square to the centre line. But if the bend has no straight portion, as in the present case (Fig. 248), then the ends of the pattern will need curving somewhat, as shown on the figure. Theoretically, no curvature at the ends should be necessary, as the area of sheet metal on the patterns, as calculated by the above rules, is exactly equal to the area of the pipe bend surface. Practically, however, it is impossible to draw metal evenly, and for some short distance from the ends, generally equal to the radius of the pipe, the sheet or plate will hardly be drawn at all. This difficulty is usually overcome by making each strip slightly longer than required and then trimming the ends off the pipe. If desired, though, the curvature of the ends can be approximately obtained in the following manner: Draw the neutral lines on the patterns (Fig. 248) by making the distance 2 to 1 on each side of the centre line equal to the length of the arc 2 to 1 on the semicircle in the elevation. Now make  $a b$  on the back neutral line equal to the radius of the pipe. Join  $a$  to  $O$ , and draw  $b d$  parallel to  $a O$ . Then the length  $c d$  will be measured off and set on the pattern, as shown. There should be no trouble in finding the radius, so that an arc can be drawn passing through  $d$  and the end of the neutral lines. This radius is shown on the back pattern, marked  $E d$ . If required, the length of  $c d$  can be calculated from the following rule: "Square the diameter of the pipe and divide it by  $6\frac{2}{7}$  times the radius of the back neutral line." That is in this case

$$c d = \frac{5\frac{1}{2} \times 5\frac{1}{2}}{6\frac{2}{7} \times 16\frac{1}{2}} = \frac{9}{3\frac{1}{2}} \text{ in. (nearly).}$$

In working a throat piece into shape, it will be found that the girth near the middle becomes, through the draw, some-

what less, and for the same reason the girth of the back will increase; consequently, when the two halves come together the joint line will be slightly out of the centre of the side of pipe. This can be modified if necessary by adding on to each side of the throat pattern and deducting from each side of the back pattern a length equal to "the square of the diameter of the pipe divided by seven times the radius of the throat," so that the camber *g h* of the side dotted curves will equal—

$$\frac{5\frac{1}{2} \times 5\frac{1}{2}}{7 \times 12} = \frac{1}{4} \text{ in. (nearly).}$$

This distance should be set out as shown by *g h* on the pattern, and an arc of a circle drawn, as seen by the dotted curves.

The patterns as marked out above will be the net size, and any allowance for trimming or jointing must be added on. If the side seams are to be riveted, then a proper allowance for lap must be made; but if brazed, by thinning the edges down to form a wedge-joint, then little or no allowance will be needed, as the width of lap will be worked down out of the sheet metal.

### Bend Less or Greater than a Quarter.

A bend may require making to joint up two lines of piping that are not at right angles, or to fit on to two flange faces that are not square to each other.

Suppose the centre lines of the piping make an angle of  $105^\circ$ , as shown in the elevation, Fig. 248, then the flange faces will make an angle of—

$$180 - 105 = 75^\circ$$

with each other. This angle can be set out as shown in Fig. 248, and thus the shape of the bend determined. The

lengths of the back and throat patterns can be found as explained in connection with the quarter-bend, or they can be calculated by the following general rule, which applies to all cases. Rule for length of back pattern: "Multiply the radius of the joint line by 6 $\frac{7}{8}$ , add twice the diameter of pipe, multiply by the angle that the flange faces make with each other, and divide by 360." Rule for length of throat pattern: "Multiply the radius of the joint line by 6 $\frac{7}{8}$ , deduct twice the diameter of pipe, multiply by the angle that the flange faces make with each other, and divide by 360." Thus for the 105° bend, as marked out in Fig. 248, the length of back will be—

$$\frac{(14\frac{3}{4} \times 6\frac{7}{8} + 2 \times 5\frac{1}{2})}{360} \times 75 = 21\frac{17}{28} \text{ in.}$$

And the length of throat will be—

$$\frac{(14\frac{3}{4} \times 6\frac{7}{8} - 2 \times 5\frac{1}{2})}{360} \times 75 = 17\frac{1}{42} \text{ in.}$$

The difference between the lengths of the back and throat patterns can be readily calculated, without using the above somewhat cumbrous rule. Thus: "Multiply four times the pipe diameter by the angle between the flange faces and divide by 360." So that in the above example the difference will be—

$$\frac{4 \times 5\frac{1}{2} \times 75}{360} = 4\frac{7}{12} \text{ in.}$$

In any kind of a bend, before proceeding to shape the plates, wires should be bent to the shape of throat, joint, and back curves, these being used as templates to which the two halves will be bent. If no special appliances are about in the shape of blocks, dies, etc., on which the parts can be

worked, then the throat part can be manipulated on a heavy mandrel or tee-stake. The back can be hollowed on a hollowing block, and dressed into something like shape on a curved top tee-stake, bullet-head stake, or cod fixed on bar. Care must be taken that the plates are kept properly annealed as they pass through the various operations. After the halves are shaped to the templates, if required to be brazed, the edges should be thinned down and properly

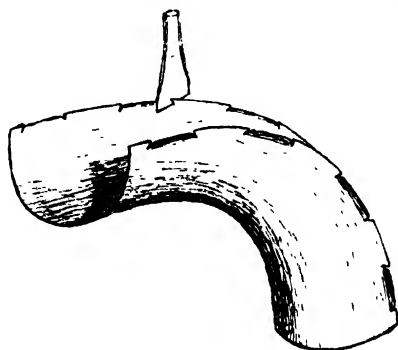


FIG. 249.

cleaned. The cramps are then cut on one half with a thin knife or chisel, which is held obliquely across the edge of the plate whilst being driven into the metal, as seen in Fig. 249.

The two halves are then fixed together and fastened with binding wire, and the cramps dressed down on a cod, as shown in Fig. 250. The bend will then be brazed and hammered up, as explained in Chapter XXXV.

### **Worked-up Breeches-Piece.**

The methods applied to obtain the patterns in the last cases can with some little modification be used for all sorts of

made-up bends. We will now explain the application to a three-way piece, as shown in Fig. 251. This kind of job can be made up in three pieces, the two side parts which form the waist and outside of legs, and one part which forms the inside of legs, or it can be formed of five pieces, three as above, together with a triangular gusset on each side.

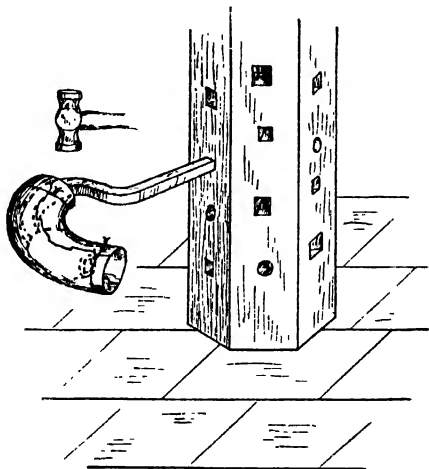


FIG. 250.

The patterns as set out in Fig. 252 are to build up the bend in three pieces. A half-side and half-end elevation of the bend is drawn, and it should be remembered in connection with this that the area of the waist pipe circle should be equal to the areas of the two leg-pipe circles added together. The leg-pipe being 4 in. diameter, the diameter of the waist-pipe will be equal to—

$$\sqrt{4 \times 4 \times 2} = 5.7 = 5\frac{3}{4} \text{ in. (nearly).}$$

Instead of bothering to calculate, the size of waist-pipe can

readily be found by construction. Set out *A B* and *B C* at right angles (Fig. 253), each respectively equal to the radius of the leg-pipes, whether they are the same size or not; then *A C* will be the radius of the waist-pipe. In connection with this figure it is worth while noting that if *A B*, *B C*, *C D*, and *D E* are equal and drawn to form

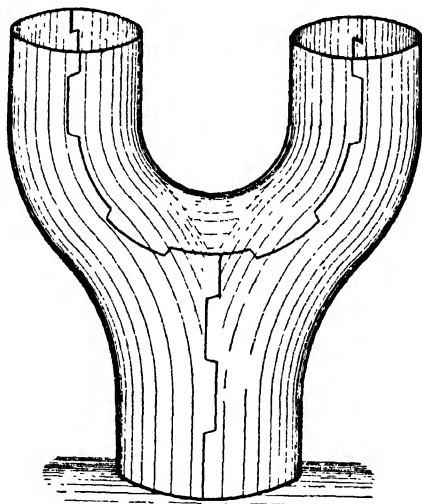


FIG 251.

right-angled triangles, then the lines *A B*, *A C*, *A D*, and *A E* will give the radii of circles whose areas are as 1 is to 2 is to 3 is to 4.

To draw in the neutral lines (Fig. 252), their positions on the waist and leg-pipes are calculated as explained in connection with the quarter-bend.

For the waist and outside leg pattern, make the centre





the pattern describe the arc K G, making it equal in length to the line O H on the elevation. Join L to G, and draw the side curve, and the net pattern is complete.

The pattern for the inside of legs will be equal in length

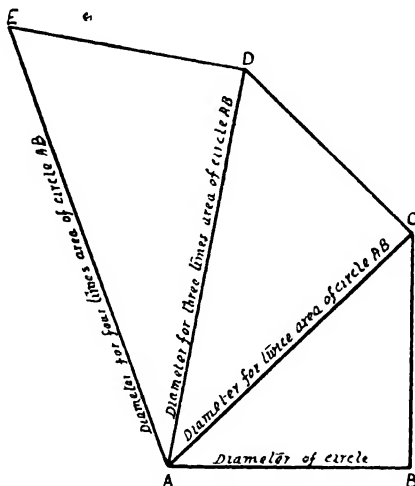


FIG. 253.

to the neutral line for that portion, and its width made equal to half the circumference of the leg-pipe.

### Three-way Tee-Piece.

A sketch of this is shown in Fig. 254. The tee-piece may be of two shapes, one when the bulb is greater in diameter than the diameter of the large pipe as in the sketch, and the other when it is of the same diameter, and consequently the sides straight as in the half-end elevation, Fig. 255. We shall get the pattern out for this latter shape, as the setting out for the bottom portion, when the bulb is larger

than the main pipe, will be dealt with in connection with a four-way piece.

A half-side and end elevation is shown in Fig. 255, and on examination it will be seen that the parts of the main and branch-pipes are cylindrical in shape; hence if the tee-piece were made up in three parts as in the last case, the pattern could be set out in the same way, or, as before mentioned, gusset-pieces could be inserted on each side. We shall, however, explain the method of working up from two pieces only, and jointed as in Fig. 254.

The neutral lines should be marked on the side elevation,

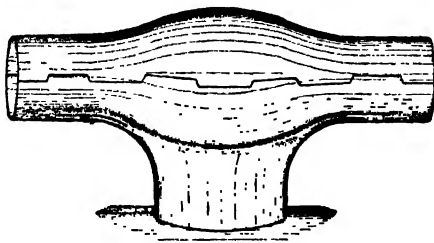


FIG. 254.

as shown. The pattern for the top piece can be set out by describing a circle, with radius equal to  $CD$  from the elevation, and then setting lengths along by marking off  $AB$  on the pattern equal in length to the neutral line  $AB$  in the elevation. The width of the ends is, of course, equal to half the circumference of the branch pipes. In cases like this, where the area of the main pipe circle is twice that of the branch pipe, it is worth noting that the diameter of the circle for the pattern of top part is equal to twice the diameter of the branch pipe.

The pattern for the bottom portion of the tee-piece is not so easily obtained. It is as well at the onset to keep in

mind that the area of a pattern for an object which has to be worked up by hollowing or razing should be at least

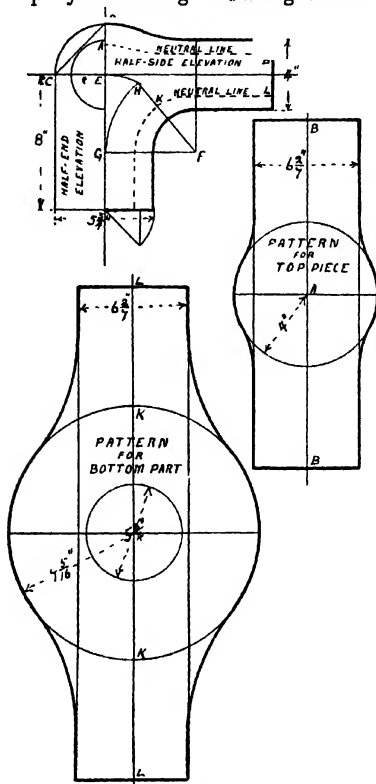


FIG. 255.

equal to the area of the surface of the finished article. This fact assists us considerably in calculating the sizes of the pieces of sheet metal required.

In the present example the diameter of the main pipe is 5·7 in., and the depth of the cylindrical part 8 in. What we require is to obtain a circle equal in area to the cylindrical surface plus the area of a 5·7 in. diameter circle. Put in the form of a rule, we have: "Radius of pattern circle is equal to the square root of the pipe diameter multiplied by the depth added to the square of the radius." Which, in this case, will work out—

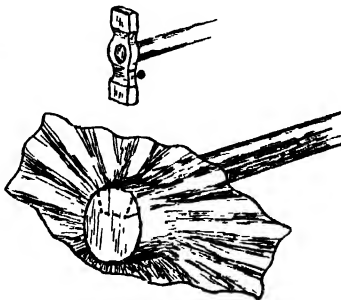


FIG. 256

$$\begin{aligned}\text{Radius} &= \sqrt{\left(\frac{5\cdot7}{2}\right)^2 + 5\cdot7 \times 8} \\ &= \sqrt{53\cdot72} = 7\cdot32 = 7\frac{5}{8} \text{ in. (nearly).}\end{aligned}$$

After describing the circle to the above radius, turn to the elevation (Fig. 255), and with centre F and radius F G, draw the arc G H; then with centre G and radius G F, mark

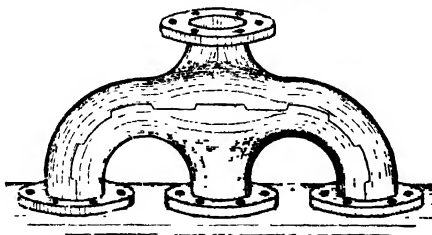
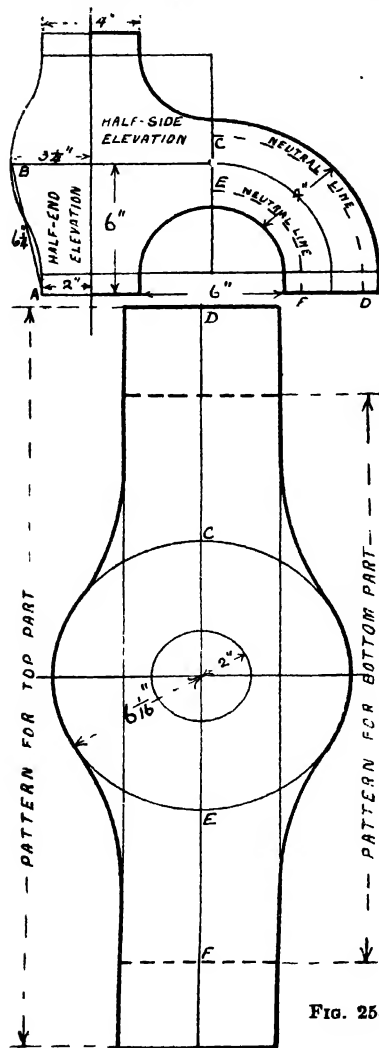


FIG. 257.

off H, and join up to F. The length of the neutral line K L will give the length to add on to the pattern circle, as shown.



The bottom portion of the tee-piece can be raised as shown in Fig. 256, and when worked into the required shape, the disc cut out at the bottom of the main pipe.

#### Four-way Piece.

For the purpose of showing how to deal with a job that brings in conical work, we will conclude this chapter by going over the setting out of patterns for a four-way piece, each pipe being the same diameter, and the plates jointed as shown in Fig. 257.

The half-side and end elevations are shown in Fig. 258. It will be seen that A B on the end elevation represents the slant side of a frustum of a cone whose ends are 4 in. and 6 1/2 in. respectively in diameter. Now, to get the size of the pattern circle we shall have to find the radius of a circle whose area is equal to the surface of the cone

FIG. 258.

frustum, together with the area of a 4 in. circle. To do this the following rule can be used: "To the sum of the end radii multiplied by the slant height add the square of the pipe radius and extract the square root of the whole." In the present example—

$$\begin{aligned}\text{Radius} &= \sqrt{(3\frac{1}{4} + 2) \times 6\frac{1}{4} + 2 \times 2} \\ &= \sqrt{36\frac{1}{8}} = 6\frac{1}{8} \text{ in. (nearly).}\end{aligned}$$

Set a circle out to this radius, and for the bottom part add the length of neutral line E F on to each end of pattern. The pattern for the top part will be obtained by measuring the length of neutral line C D, and setting along on the pattern. It will be noticed that the pattern for the top part is just twice the diameter of the pipe greater in length than that for the bottom portion. This, of course, follows from what was said in connection with the quarter-bend.

To make proper allowance for the thickness of metal, all the above patterns should be set out to dimensions taken from the centre line of the plate sections in elevation.

## CHAPTER XXX.

## KETTLE AND JUG SPOUTS, HANDLES, ETC.

## How to Make a Kettle Spout.

THE making of a kettle spout, to the novice, is just one of those jobs for which it is somewhat difficult to find a beginning or ending without previous instruction. Spouts are usually made up from one piece of sheet metal, the marking out of its shape presenting no great difficulty. In Fig. 259 the necessary lines required for the development of the pattern are shown laid out. The spout is first straightened out, as it were, in imagination, by making line  $a c$  equal in length to the curve  $a b$ ; the diameter at  $c$  being made the same as the spout end. The centre line  $A C$  on the pattern is cut off the same length as  $a c$ , the lines  $D D$  and  $E E$  being drawn square across, and their lengths fixed by marking off  $A D$  and  $C E$  respectively equal to three and a quarter times  $a d$  and three and a quarter times  $c e$ . The lines  $C E$  and  $A D$  are each bisected in  $G$  and  $F$  respectively, and the line  $G F$  drawn and produced to  $H$ ,  $F H$  being made equal to  $a h$ . The angle  $F H K$  is next constructed by drawing an arc of the same radius and length as  $m l$ ;  $H K$  then being measured off the same length as  $h k$ . The compasses are next set to a radius of a little more than one and a half times  $l p$ , and the arcs drawn as shown at  $P$ . In the same manner the arcs are drawn at points marked  $N$ . The lines  $N N$  are put into position by constructing them to make the same angle with  $K H$  as  $n n$  makes with  $k h$ . The small lug shown at  $R$  is the usual shape for sheet iron,



and assists in forming the heel of the spout; the dotted lug shows a suitable shape for a copper spout. Instead of the ends N N being made straight, it will be an advantage to

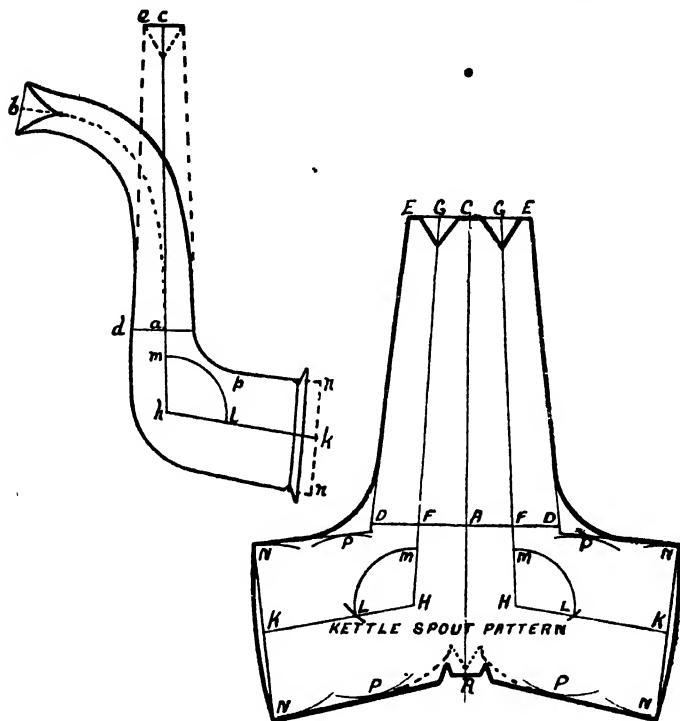


FIG. 259.

curve them a little, as shown on the figure. The shoulder curves are drawn to touch the lines N P and E D, and should be to a radius of about one and a half times that for the inside of the spout.

In working up, the plate is first bent a little, and then

stretched on the shoulders, as shown in Fig. 260. This stretching enables the two edges of metal to come together



FIG. 260.

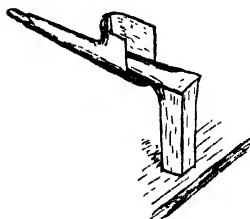


FIG. 261.

when the tapered pipe portion is formed, as seen in Fig. 261. When the edges are lapped over a little and carefully laid down, the seam can then be brazed, as shown in Fig. 262.

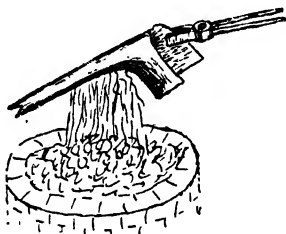


FIG. 262.

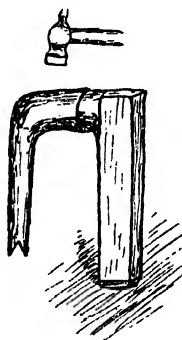


FIG. 263.

The usual method of brazing is to bend a strip of sheet brass to the form of the joint, and when on the fire, start the brass to run at one end and gradually work along the seam to the other. A good sound brazed joint can quickly be done in this way. After the seam is hammered, the heel is formed, as shown in Fig. 263, by turning the small lug down first,

and then lapping the sides upon it. The back seam is brazed, and the heel of spout carefully shaped on a block tool, as shown in Fig. 264. The edge of the spout mouth is now trimmed, and a groove and collar formed around it

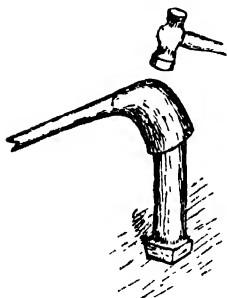


FIG. 264.

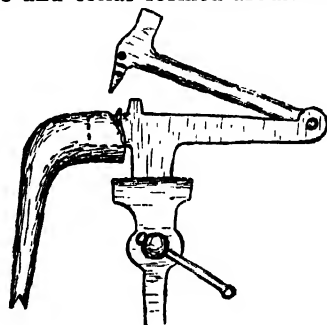


FIG. 265.

—to fasten to kettle body—by a hand bumping-swage, as seen in Fig. 265. The spout is next filled with lead for the

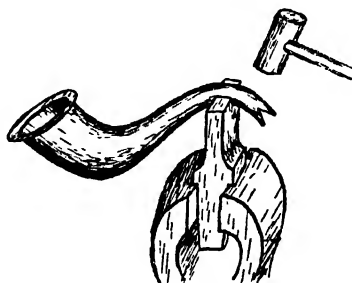


FIG. 266.

purpose of bending, the end being first stopped by twisting a piece of stout brown paper around the outside for a distance of about 2 in., and over the end. The bending is carried out as shown in Fig. 266, the tool being shaped to the diameter and bend of the spout end. The bending must

be done gradually, to avoid buckles on the underside or cracking on the top. If any buckles appear, these must be hammered out before the lead is melted from the spout. A small crack on the top of the spout can be repaired by hammering a piece of wire flat for a short distance, wrapping it around the pipe, brazing, and cleaning. After the lead is run out, the end should be rounded up and the lips opened somewhat and trimmed with a V-file. In a kettle

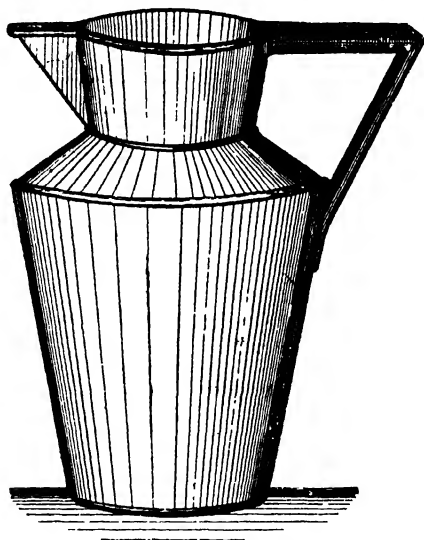


FIG. 267

factory, it might be mentioned, all the above operations of cutting and shaping are carried out by the aid of presses fitted with suitable dies.

#### **Square Spout for Conical Jug.**

A square spout for a jug, as seen in Fig. 267, represents a good example of flat sheet surfaces fitting on to a conical



$lh$ , and  $R N$  equal to  $rn$ , the curve  $H B H$  being, of course, twice the part of ellipse represented by  $b h$  on the elevation. To fit exactly on to the conical surface, the edge  $H N$  should be slightly hollow; but this, if found necessary, can be put

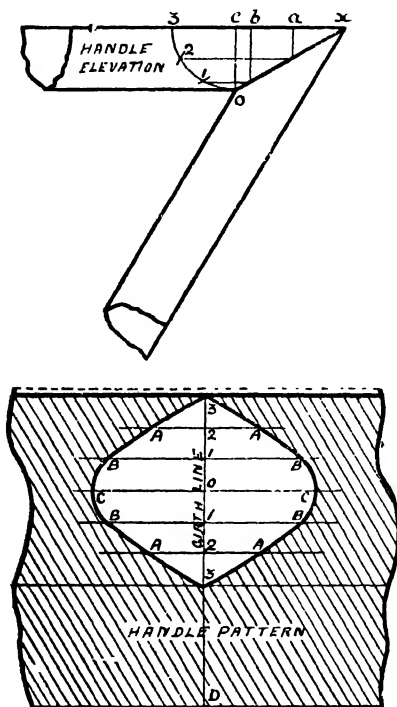


FIG. 269.

right when bending the flange over. If a not very particular job, there is really no need to cut away the part  $H B H$ , as the edge  $H H$  can be curved around the neck at the part where it fits.

### Curved Spout for Conical Jug.

The method for setting this out will be exactly the same as that shown for the sponge bath lip in Chapter XVI.

### Half-Round Jug Handle.

The jug in Fig. 267 is fitted with a half-round hollow handle, and if it is desired to make this in one piece, the pattern for same can be struck out as shown in Fig. 269. A quarter-circle is described on  $O c$  and divided into three equal parts, lines then being run along to the joint line  $O x$ , and up, to give the points  $a$  and  $b$ . The girth line of the pattern is laid out by taking six divisions, each equal in length to one of the arcs on the quarter-circle added to  $3 D$ , which is the width of the handle, and equal to twice  $3 c$ . The points  $A$ ,  $B$ , and  $C$  on the pattern are found by marking off  $2 A$ ,  $1 B$ , and  $0 C$  respectively equal to  $x a$ ,  $x b$ , and  $x c$  from the elevation.

In forming this handle section, the part  $3 3$  will, of course, be shaped into a semicircle, whilst the portion  $3 D$  will turn over to give the flat. The joint will run along one edge, and after this is formed, the mitre can be made by simply bending along the line  $3 D$  until the two curved edges,  $3 C 3$ , come together.

## CHAPTER XXXI.

## VASES, BRACKETS, DUSTPANS, ETC.

THERE are a great many different things that can be constructed in sheet metal which are particularly suitable for making by the amateur.

It is true that some of them can be bought for a few pence, but the amateur with the true workman's instinct will find an immense amount of joy in the feeling that he has constructed something for his own use or pleasure.

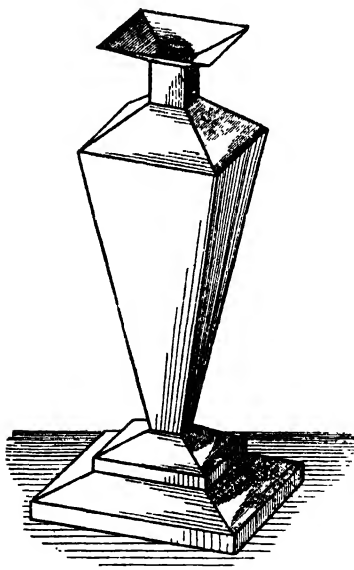


FIG. 270

We shall now give one or two examples of sheet metal work, which, on account of their simplicity of construction and the few tools required in their manufacture, can readily be made up. Many neat-looking ornaments, such as vases, candlesticks, flowerpots, jugs, wall-brackets, pedestals, and such like things,

can be made up out of strips of metal mitred together, with very little trouble.



Fig. 270 gives a view of a candlestick that may be constructed out of either sheet zinc, copper, or brass. For those who have not attempted work of this kind before, it will, perhaps, be the best plan to commence with thin zinc, say, No. 10 (zinc gauge). To simplify the work as much as possible, a square form of candlestick has been chosen, which is made up

out of four strips of metal jointed at the corners. To mark out the shape of a strip a half-elevation of the candlestick is first drawn, as in Fig. 271. Each point is numbered as shown, and it will thus be seen that the total length of a strip must be equal to the sum of these numbered lines. Set the lengths 0 1, 1 2, 2 3, etc., down a line which will form the centre line of the pattern, and draw lines through these points square to the centre line. The width of the pattern at the different parts is obtained by setting on each side of the centre line of pattern the length of the line with the same number which is

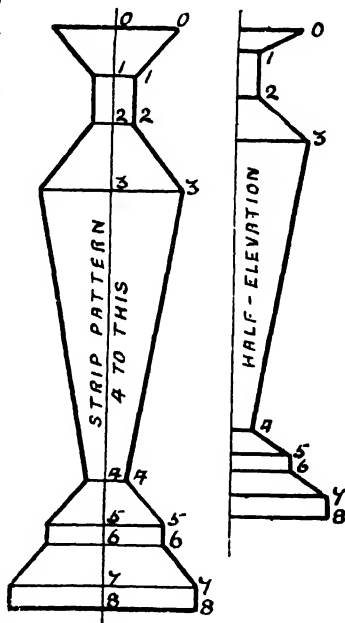


FIG. 271.

drawn from the point to the centre line in elevation. The points found are now joined with straight lines, and the pattern for one strip is complete. The greatest accuracy must be aimed at in setting out a strip, as any inaccuracy in the pattern will cause endless trouble in jointing the

strips together. Four pieces are cut out to the pattern, and the lines for bending carefully marked. The strips can be bent to the required shape over a sharp edge of any kind, either on a bar of iron or a piece of timber. In bending, care must be taken that the centre line of the strip be of exactly the same form as the outline of candlestick in elevation. It will be as well to cut out the half-elevation in cardboard, and use it as a template to try on the bent metal strip, and thus by continual bending get them to the exact shape. In thin zinc the strips can be bent by the hand without using either mallet or hammer; but in any job on which the hammer is used, it should be seen that no hammer marks are left on the sheet, or else the finished appearance of the article will be anything but pleasing. If the strips are marked and cut correctly, and bent to the exact shape, there should be no trouble in making them fit together. None of the operations should be hurried, but great pains taken over the work, and this will save a lot of time and bother in the afterwork. In fitting the strips together it will be the best plan to tack them all in position before proceeding to completely solder along one corner joint. The best way to fix a corner will be to bring together two strips, and tack with solder the two points 0 0, then do the same with 1 1, 2 and 2, etc. After the four strips are tacked together at all the corners, the candlestick should be examined and tested as to being properly square. It should also be placed upon a level table to see if there is any twist in it. When in good shape the joints should be soldered down, as much of this being done from the inside as possible. In this case both the foot and top can be soldered from the inside. the joints of the body being done from the outside. In soldering, care must be taken that the iron does not get too hot, or else the flat parts of the strips will buckle, and cause the surfaces to have an ugly appearance. This is

especially so with light sheet zinc. A square bottom is now cut out, allowing about  $\frac{1}{2}$  in. all round for bending over an edge. The bottom is tacked at each corner inside the foot, and then soldered along each edge. If required the foot of the candlestick can be weighted by first of all stopping up the stick at 4 by soldering in a small square of zinc, then filling up the foot with sand before soldering in the bottom. A stopper might also with advantage be soldered at the bottom of the neck; this would be best done before the last strip is tacked in. The superfluous solder must be scraped off the joints and the corners carefully filed up, and if the stick be cleaned and polished, the job is finished. A small quantity of killed spirits can be used to clean the zinc, and oil and whiting to polish, or finish with a good polishing paste.

If a candlestick is made out of copper, the solder at joints can be coated with copper by applying a solution of sulphate of copper. It will then be an advantage if, after well polishing, the surface is lacquered.

### Hexagonal Vase.

Fig. 272 shows a sketch of a simple kind of hexagonal vase that can be made up either of tinplate, zinc, galvanised iron, brass, or copper. A half-elevation, Fig. 273, shows the exact shape or section of one side of the vase. From the point where the centre line meets the base line a joint line making an angle of  $30^\circ$  with the base line is drawn. The required angle to set out will, of course, depend on the number of sides the vase has. The general rule for obtaining the number of degrees is a simple one: "Divide 360 by twice the number of sides." In the present case the vase has six sides; hence the angle to set out is 360 divided by 12 =  $30^\circ$ . The profile of vase in elevation is now divided up, giving points 0, 1, 2, 3, etc., up to 16. Dotted lines

perpendicular to the base are drawn through each of these points, and continued across the base line to meet the joint line. To set out the shape of one of the strips a centre line is drawn, and along this the lengths 0 to 1, 1 to 2, 2 to 3, etc., taken from the elevation, are marked. Lines square to the centre line are drawn through each point, and the lengths of these cut off equal to the length of the line with the same number between base and joint lines in elevation. Thus, to mark off line 0 0', turn to point 0 in the elevation,

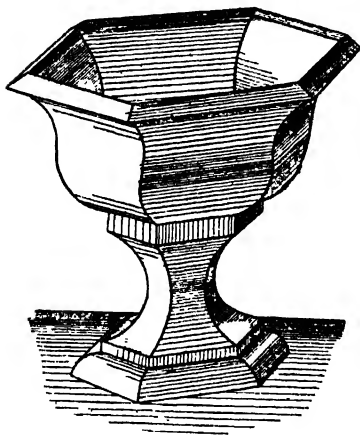


FIG. 272

follow the dotted line down to base line, and measure along the continued line between the base and joint lines; this will give the length 0 0'. In the same way obtain and set along the lengths 1 1', 2 2', etc., each side of the centre line in pattern. Carefully join these points up with curves or straight lines as required. It will be noticed that where lines are straight in the elevation the corresponding lines on the pattern will also be straight. For instance,

lines 0 to 1, 7 to 8, and 13 to 14 are straight in the elevation, hence 0' to 1', 7' to 8', and 13' to 14' will be straight in the pattern. Remembering this, it will always act as a guide in joining up the points in the pattern for a strip.

The bending of the parts can be carried out in the same manner as in the case of the candlestick, the curved portions being bent over a wooden roller. Before tacking the strips together a template (Fig. 273) for 120° should be cut out of

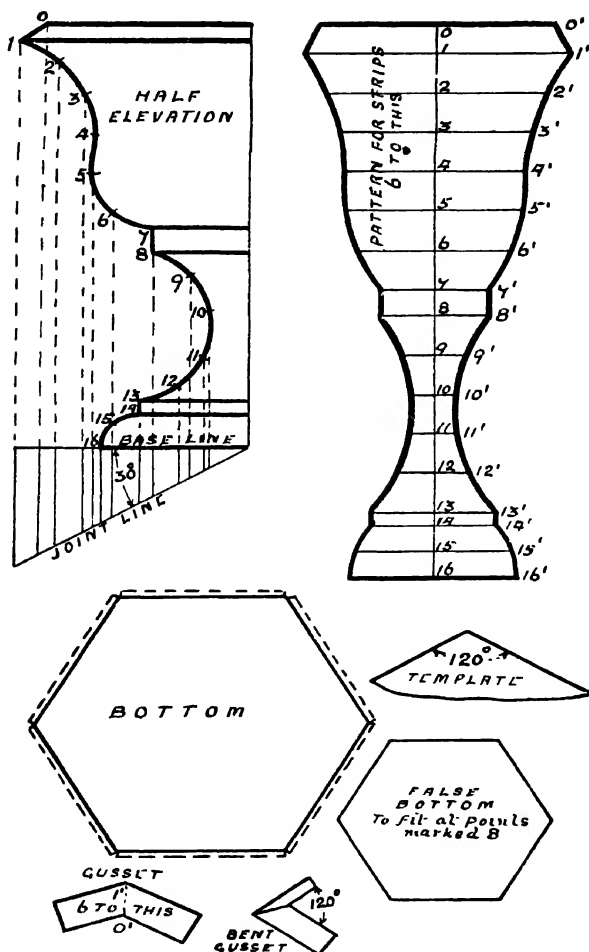


FIG. 272.

a bit of sheet metal. This can be used for trying in between each pair of strips as they are being tacked together. After all the strips are tacked in position, and before completely soldering, the diameters should be measured to see if they are all the same. The vase should also be examined to observe if it has any twist.

In this shape of vase it will be found that all the joints can be soldered down the inside. A bottom should be cut out, as in Fig. 273, allowing a small margin all round for turning an edge up. This edge is slipped inside the foot, and will facilitate the soldering, besides strengthening the edge of foot.

The top corners of vase will be much stronger if a small gusset (Fig. 273) is soldered over each joint. This gusset can be marked out from the top part of strip pattern, its centre line being equal in length to 0' 1'.

Any size vase can, of course, be made. It may, however, act as a guide to know that the drawings have been made to scale for a vase 10½ in. diameter (across the flats) at top.

If the vase be a large one, and made out of tinplate, zinc, or galvanised iron, its appearance will not by any means be inartistic if painted a dead chocolate, green, or any other colour in harmony with its surroundings.

### **Tobacco or Biscuit Box.**

A sketch of a square box is shown in Fig. 274, the body being made up in four pieces, and jointed at the corners. The lid is in form a square pyramid, and is worked up from one piece, as will be further explained.

To set out the patterns for the different parts, it will be necessary to draw the shape to which the sides of the box must be bent. This is shown on the half-sectional elevation in Fig. 275.

The pattern for one side of the body is obtained by marking down a girth line, and setting along it the lengths 4 to 5, 5 to 6, etc., up to 15, as taken from the sectional elevation. It should be noticed that the lengths from 4 up to 7 are obtained by measuring around the small circle on the section, which represents the bead on the top edge of box. After the total girth is set out, then lines square to the

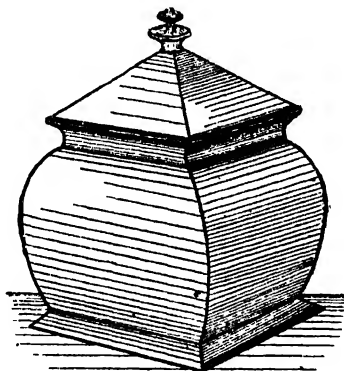


FIG 274.

girth line should be drawn through each numbered point. The lengths of these lines each side of the girth line should then be marked off equal to the similarly numbered lines which run from the centre line up to the curve on the section. To take one case: the line numbered 9 9 on the pattern should be the same length as the line numbered 9 9 on the half-sectional elevation. After all the lengths have been carefully cut off, then the points should be joined up with an even curve. On account of the foot having straight sides it will be noticed that the cut on the pattern which forms the foot will be made up of straight lines.

The lid of the box is pyramidal in shape, and therefore

the making of the pattern is a simple matter. With radius equal to  $O 1$  on the elevation describe the pattern circle (Fig. 275). Draw a line touching this circle, and on each side of the point of contact cut off distances  $1 A$  equal to the length of  $1 A$  on the elevation. After one line  $A A$  is

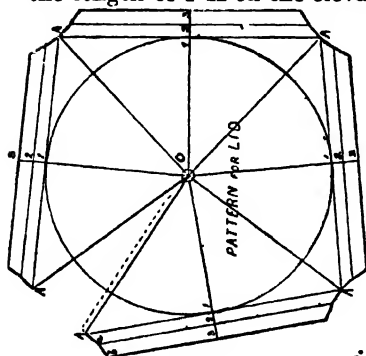
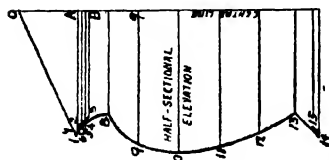
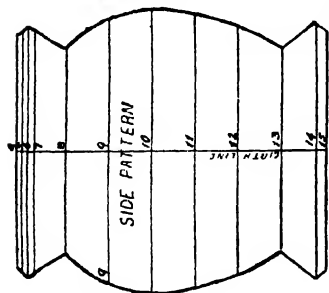


FIG 275.



drawn, then the other three lines with the same letter can be drawn around the circle as shown. Strips now require to be added to form the rim of the lid. Take off the lengths  $1$  to  $2$  and  $2$  to  $3$  from the elevation, and transfer to the pattern, as seen by the same numbered lines. Now draw lines through the points parallel to  $A A$ , and cut these off to the corresponding lengths on the elevation. That is, make  $2 a$  on the pattern the same length as  $2 A$  on the elevation, and  $3 b$  on the pattern the same as  $3 B$  on the elevation. A small lap, as shown by the dotted lines, should be allowed on one edge of the lid pattern for jointing.

Now to make up the article. If made of copper or brass, it will be essential to coat the inside of the

sheet metal with tin. This can be done in the ordinary way



by first cleaning the surface of the metal, sprinkling over with a flux, such as salammoniac, and then putting a few bits of tin on the sheet and heating over a gas or clean coke fire, and wiping off with a piece of dry cloth or tow. To avoid the tin running on to the side of sheet that is not required to be coated, it is a good plan to first brush its surface over with some whitening paste.

In shaping the four side-pieces that go to form the body, the small bead at the top should first be put on. This can be done by bending the edge along, doubling it over a piece of wire of the right size, carefully tucking the edge in, and then withdrawing the wire. The edge at the bottom of the foot should next be folded over and lightly flattened down. Each of the four pieces can then be formed into shape, and it should be remembered in connection with this that the centre line on the pattern must conform to the exact shape of the half-sectional elevation.

Before proceeding to completely solder down any one corner, all the pieces should be tacked together, and the body tested as to shape, and also if level across the top and bottom. The edges of the sheet down the corners should be brought into contact as far as possible, so as to avoid any appearance of solder on the outside of joint. The soldering should, of course, be done down the inside of corners, a fair body of solder being left on so as to strengthen the joint. The bead around the top may also be made stronger at the corners by bending small pieces of wire at right angles, and inserting in the bead before tacking.

The pattern for the bottom is not shown, as it will be simply a square piece of sheet metal the size of which will be equal to the length of line drawn through the point 13 on the side pattern. The bottom plate will, of course, be tinned on one side, and fastened to the body by soldering all round.

The sheet metal for the lid can be brought into shape by

bending along each of the corner lines marked O A until the end lines of the pattern come together. The joint should then be formed by fixing the lap on the inside of the lid and soldering down. The double edge to form the lid can then be bent, as shown in the sectional elevation. A hole is made in the centre of the lid, and a knob to suit the individual taste soldered in.

After cleaning away all superfluous solder, the outside of the box should be polished and coloured, lacquered, or treated in any other way suitable to the likes of the individual.

Whilst the making of a square box has been described, the above remarks will apply to a box of any number of sides, the only difference being that the pattern for the body will have to be marked out as explained in connection with the next example.

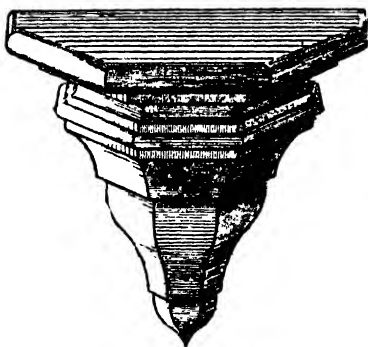


FIG. 276.

### Wall Bracket.

Another piece of work that can be made by the amateur, who exercises carefulness and patience, is the wall bracket, as shown in Fig. 276.

The shape of a wall bracket can be made up by any number of pieces; but that in the figure is partly octagonal, the three front

and two side pieces together forming five sides of an octagon. The whole number of parts in the bracket will be seven, three front, two side, and the top and back pieces.

Any convenient section for the moulding can be chosen, either simple or complex, to suit the skill of the operator

in working up, and for the bracket to give the best effect when hanging from a wall.

The setting out of the various patterns is shown in Fig. 277. The section of the moulding is first set out. A base line is drawn square to the centre line; and as the article is octagonal in shape, a joint line will be set off, making an angle of—

$$\frac{360}{\text{twice number of sides}} - \frac{360}{16} = 22\frac{1}{2}^{\circ}.$$

This angle can be set on either side of the base line, whichever is most suitable. The section line of moulding is then divided up into any convenient number of parts, and figured as shown by the numbers 0 to 23. Perpendiculars to the base line are then drawn through each point and along to the joint line, as seen by the dotted lines.

The pattern for one of the three front strips will be marked out by first laying down the girth line, the lengths being taken step by step between the numbers from the section line. Through these points lines square to the girth line are drawn, and their lengths on each side cut off equal to the corresponding line between the base and joint lines. Thus, to give an illustration, lines 0 0 and 3 3 on the pattern will be respectively equal to lines 0 0 and 3 3 as indicated between base and joint lines.

It will be seen that the cut on a side strip is exactly the same as that for a front piece, and marked out in precisely the same way. The width of the strip is obtained by making the top line equal in length to the top line of a front strip or twice the length of line 0 0 between base and joint lines, and then drawing a line parallel to the girth line. Perhaps the most convenient and accurate way of marking out the strips would be to set out the shape of a side piece first, and then use this for a pattern from which to obtain the shapes of the other four pieces.

The pattern for the back can be easily drawn out, for the exact shape of half of it is as shown by the figure which is

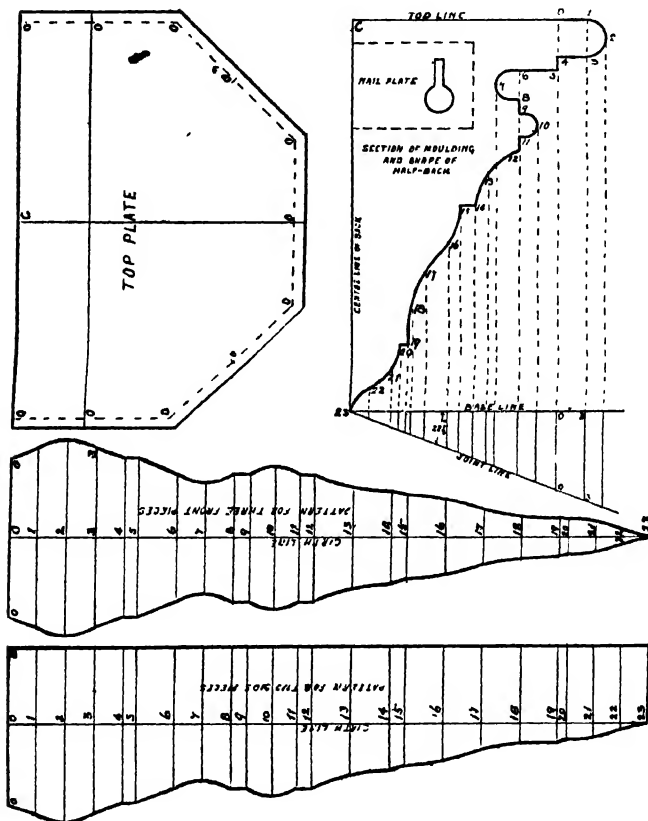


FIG. 277.

bounded by the top line, centre line of back, and moulding section on Fig. 277.

The shape of the top plate is also shown on the same figure, the dotted lines representing the exact shape around the inside of top of bracket. The lengths as marked being obtained from the lines with the same number on the section of bracket.

The top and back can be made in one piece; but this will cause some inconvenience in soldering, as all the joints should be soldered down the inside, the top plate being soldered on last of all.

To hang the bracket from the wall, a good plan will be to solder or rivet a plate on the inside of the back and to put two key-shaped holes right through the two thicknesses of metal, as shown in Fig. 277.

The bracket can be made out of sheet zinc or other suitable material, and after all the joints are carefully scraped, painted some colour that will harmonise with its surroundings.

### Phonograph Horn.

The making of a phonograph horn in segments, as illustrated by Fig. 278, is particularly suitable for amateur's work, as it can be readily constructed with few tools and at little cost of material. It may be made out of tinplate, zinc, brass, aluminium, or hard rolled copper. The horn, as shown, is made up in twelve strips jointed together and fitting into a thimble.

To obtain the pattern for a strip or segment, the profile or section of one strip is set out, as shown in Fig. 279. A joint line is drawn, making an angle of—

$$\frac{360}{\text{twice number of strips}} = \frac{360}{24} = 15^\circ$$

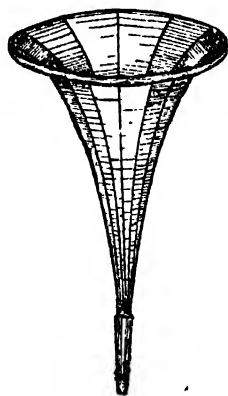


FIG. 278.

with the base line. The section curve is divided into any number of parts, four being chosen in this case. The length of this curve is carefully set out to form the girth line of the pattern for a segment. This is done by making the lengths 0 to 1, 1 to 2, etc., on the pattern equal in length

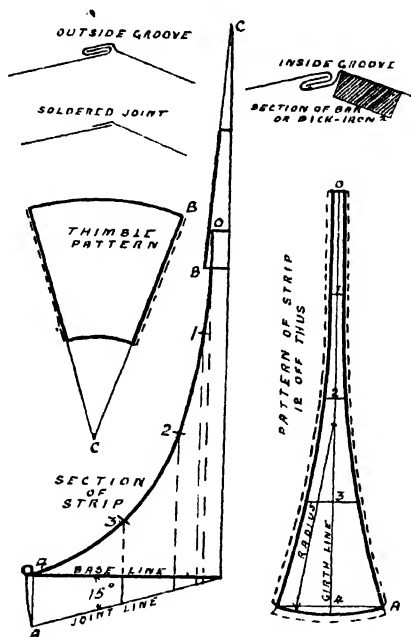


FIG 279.

to the parts of the curved line 0 to 1, 1 to 2, etc., on the section. Lines are drawn across through each point on the girth line, and these cut off on each side equal in length to the corresponding line between the base and joint lines. Thus line 4 A on the pattern is the same length as the line 4 A on the section, and so with the other lines through

points 3, 2, 1, and 0, all measured between base and joint lines. A piece of hoop iron or a lath should now be bent to pass through each point, and the pattern curve drawn in. If it is desired that the bell-mouth of the horn should come an exact circle when the strips are joined together, then the compasses must be set to a radius equal in length to the joint line, and the curve at the bottom of the strip pattern marked along as shown. The allowance for wiring around the mouth must be added on as seen in the pattern by the dotted curve.

The strips can be jointed together either by soldering or grooving. If soldered, the allowance for the lap will be as the dotted line on the right-hand side of the pattern. If grooved, an allowance on both sides will have to be made, the lap on one side being twice the width of that on the other. The double lap is shown on the left-hand side of the pattern.

The pattern for the thimble will develop out quite easily, the surface being that of a frustum of cone, and being marked out as explained in Chapter XII.

To make up the horn, the strips will first be bent so that the girth line will have the same shape as the section or profile. If to be soldered, the small lap will then be slightly bent over with a mallet, so as to lie on the adjoining strip. The strips should all be tacked together before any joint is completely soldered down. The laps and soldering should be on the outside of the horn, the joint being made as neatly and cleanly as possible. The wire edge on the bell-mouth should now be turned over, the ring of wire inserted, and the edge hammered down with the mallet, and carefully tucked in with the pane end of hammer.

If the joints of the horn are to be grooved, then the single edge must be edged up and half of the double edge turned down, this, of course, taking place after the strips are shaped. The strips can now be hooked together and grooved

(see sketch of outside groove, Fig. 279) by placing on a square bar or bick-iron and hammering the groover gently along the joint. The grooving of the narrow part of the horn will present some little difficulty; but this can be overcome by fixing on the small end of bick-iron, or by the amateur on a piece of round bar-iron held fast in a vice, or by other means.

If it is desired to have the outside of the horn plain, and consequently the groove formed on the inside, this can be accomplished by placing the joint on the edge of bick-iron or bar, hammering down with mallet to form groove, and then flattening the groove with the mallet or hammer in the usual way. A sketch of this method of forming an inside groove is shown on Fig. 279.

### Dustpans.

Of all household utensils, perhaps the most difficult to obtain is a strong, serviceable dustpan. After having put up with broken handles, cracked corners, and other defects

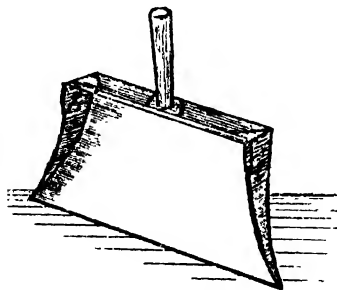


FIG. 280.

of the modern dustpan, the writer some years back devised and made a pan out of aluminium (Fig. 280), which seems to be making a fair bid towards old age without showing any signs of collapse. The dustpan is simple in construction, and can be quite easily made by an amateur.

A sheet of aluminium 14 in. by 11 in. by about  $\frac{3}{16}$  in. thick is required for the body, and for the handle and washer a piece about 9 in. by 5 in. The sheet for the



body is marked out as shown in Fig. 281, and cut down the corner lines as indicated. The back is bent up square, and the corner flaps turned inside. The sides are now bent up square, and the corner flaps of them turned on to the back. The  $\frac{3}{8}$  in. edge on the back is turned over and hammered down on to the two corner flaps, as seen in Fig. 280. The  $\frac{1}{8}$  in. edges on the sides are turned over, and the edges of the inside corner flaps turned over the sides. Thus the two corner flaps are firmly held without the use of rivets, and the corner cannot be pulled or knocked apart. This method of forming the corner also gives the additional advantage of two thicknesses of metal at the corner—the part of the dustpan that is usually the most strained. A

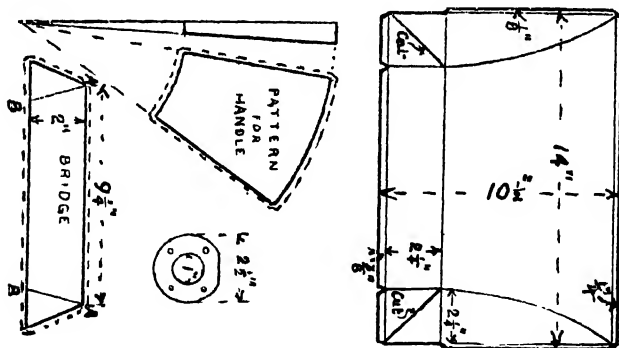


FIG. 281

lap of  $\frac{1}{4}$  in. is turned over on the front edge of the pan, thus stiffening and keeping straight this part.

The handle is  $1\frac{1}{4}$  in. diameter at one end, 1 in. at the other; and 6 in. long. This is shown set out in the usual manner. An edge is turned over on the end of handle to protect the hand from the raw edge of the sheet. The handle is jointed down with a small groove, after which

the washer is slipped on, and a small flange thrown over on to it. The washer is now riveted on to the back of the pan, and there is no danger of the handle coming loose. A hole should be put into the handle by which the pan can be hung up.

There is very little necessity to put a bridge on the pan; but, if required, the pattern can be cut out as shown in Fig. 281. To fix to the pan the bridge should be bent along the lines A B, and the outside edges doubled over and slipped under the edges on top of pan before these are hammered down, thus forming a kind of groove or knocked-up joint.

Whilst aluminium is somewhat costly for an article of the above description, it is the cheapest in the long run, being relatively strong, and of little weight when made up into the pan.

### Fire-Shovels.

A fire-shovel is another common article that can quite readily be worked up by the amateur. A simple design is that of Fig. 282, the pattern for the body of which being shown in Fig. 283. The sides and back can be bent up and

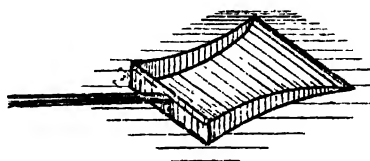


FIG 282.

jointed in the same manner as the dustpan, and will make a very good job in that form, especially if the four flaps are riveted down in the corners. The usual plan, however, and the simplest to follow, is to cut out the plate (in, say,

16 or 18 S.W.G. iron or steel), as shown in Fig. 283.\* Holes are punched in the two flaps and back, and these bent up and riveted. After the flaps are riveted, the top edge of the

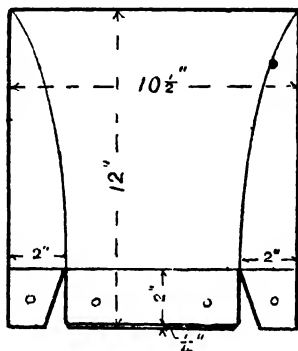


FIG. 283.

back is then turned over. A handle can be formed by bending a piece of 1 in. by  $\frac{1}{2}$  in. flat iron, shaping it according to fancy or skill. It should be firmly riveted to the back, and also to the bottom of the shovel body.

### Hand Scoops.

The cone surface, as we have seen, plays a most important part in building up the shapes of a multitude of articles. A simple application, and one that can be readily understood by the amateur, is in the construction of a hand scoop, as shown in Fig. 284. It will be seen that the handle, thimble, and back of scoop are formed by parts of cones of different dimensions. The patterns for the handle, thimble, and back are shown set out in Fig. 284 in the usual way; the letters on the lines of the different patterns being the same as the lines in the elevation to which the compasses have been set for the various radii.

The pattern for the front part of the scoop can be obtained by treating it as a portion of a straight pipe. A semicircle is drawn on the line E 4, and the bottom half divided into three equal parts. Lines square to E 4 are run through the points until they cut the front edge of scoop. It will be observed that the top edge of scoop body cuts the semicircle at the point O. A girth line is set down for the pattern and lengths 0 to 1, 1 to 2, etc., marked along as shown. Lines are

drawn through these points perpendicular to the girth line, and cut off the same length as the corresponding line in the elevation. These are shown cut off by the dotted lines, which are projected from the ends of the lines in the elevation. In practice, however, lines should be measured directly from the figure, and lengths marked off without projection. The projection method is used in the illustration to better explain how the various lines are obtained. An unbroken curve is now drawn through the points, and laps added on to the net pattern as required.

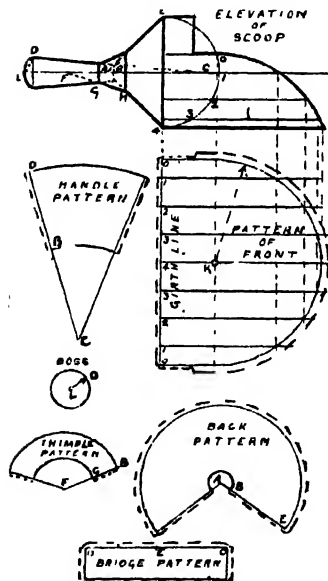


FIG 284.

When the front curve of the scoop is not required to be of any specific shape it is usually marked out on the pattern as a semicircle. Thus, in this case if centre K be chosen and half the length of the girth line taken as radius, the pattern curve will come out practically the same as that

which has been obtained by the method previously explained. But in all cases where the shape is definite the first method must be pursued.

The bridge pattern will be a straight strip, its length being equal to twice the length of the arc *O E* on the semi-circle. On the patterns for the front, bridge, and back, allowances have been made for wiring, for grooving bridge to front, and for knocking up along the joint *E 4*. If there is to be no wiring, or if the joints are to be soldered instead of grooved, then the allowances must, of course, be somewhat different.

The radius for marking out the boss blank will be equal to the line *L D* in the elevation.

The handle, thimble, and back will be fastened together by firmly soldering; also the boss will be just let into the end of handle, soldered, and cleaned off. A small disc should be soldered in the back at *B* to block up the hole, or this can be accomplished by cutting the back pattern out as for that of a complete cone.

## CHAPTER XXXII.

## PLATER'S WORK, TANKS, SHELLS, ETC.

**Allowance for Metal Thickness.**

It is absolutely essential in the making of patterns or templates to cover for the necessary allowance for the thickness of sheet or plate if the different parts that form the article are to fit together correctly. In general sheet metal work the allowance to be made for thickness is not so important as in plate work; but, in any case, if a good-fitting job is required some thought must be exercised, so as to make the requisite modification of pattern to cover for the different thicknesses of metals. In plate metal work it is of the greatest importance that patterns should be so marked out that the thickness of plate is properly allowed for, as in this class of work a job is completely botched if rivet-holes are half-blind, and have to be gouged, reamed, or drifted.

To illustrate the method adopted in allowing for thickness, suppose the following experiment to be carried out: A straight bar of metal is taken and a line N N (Fig. 285) marked along the centre of one side; also two parallel lines are drawn across the bar, such as E C and F D. Now if the bar be bent as in the lower figure, the lines will fall into the positions shown. If the line E F be measured both before and after bending, it will be found to have lengthened in bending, and in the same manner if C D be measured, it will be found to have shortened. The line A B, however, will be the same length as before bending. From this it is evident that the whole line N N will remain of

constant length as the bar is bent. This line is called the "neutral axis," and in every bent bar or plate it will be possible to find the position of some line that has been unaltered in length by the bending.

Every plate metal worker who is interested in the principles underlying his trade should make several experiments on bars and plates similar to the one above-mentioned. If the plates or bars are bent hot, care

must be taken that they are uniformly heated, or else the elongation and contraction will be unequal. For instance,

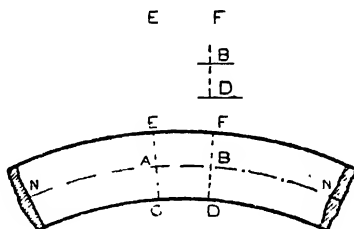


FIG. 285.

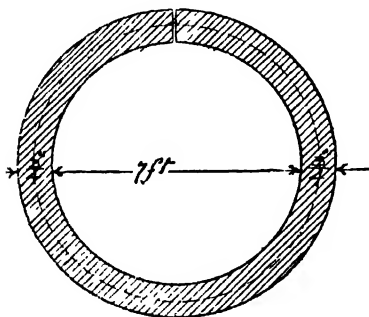


FIG. 286.

if the outside of the bar is hotter than the inside, most of the draw will take place on the outside, on account of the bar being softer; but if the inside be the hottest, then nearly all the draw will be on the inside.

In square, flat, and round bars the neutral line will always pass through the centre of

the section; similarly, if sheets and plates are bent, the neutral line will be at the middle of the thickness of metal. Angle-iron, tee-iron, and other sections will be dealt with later.

If it is required to obtain the length of a plate to bend into a complete circle, as in Fig. 286, this can be done in

two ways—either by setting out and measuring along the centre line of the plate, or by calculation. Suppose the inside diameter to be 7 ft., and the thickness of metal  $\frac{3}{4}$  in., then the diameter of the circle formed by the neutral line will be 7 ft.  $0\frac{3}{4}$  in. Multiply this by  $3\frac{1}{4}$  we have—

$$84\frac{3}{4} \times 2\frac{1}{2} = 266\frac{5}{14} \text{ in.} = 22\text{ft. } 2\frac{5}{14} \text{ in.}$$

If the number 3.1416 be used to represent the ratio between the circumference and diameter of a circle, then the above will run out—

$$84.75 \times 3.1416 = 266.2506 = 266\frac{1}{4} \text{ in.}$$

In all work where accuracy is required, the number 3.1416 should be used.

It will be noticed that before proceeding to calculate, the thickness of metal was added to the inside diameter, and it will thus be seen that the girth of plate to form a circle will always be  $3\frac{1}{4}$  times the thickness of the metal greater in circumference than the circumference of the inside of pipe.

If a plate is to be bent in any form, such as Fig. 287,

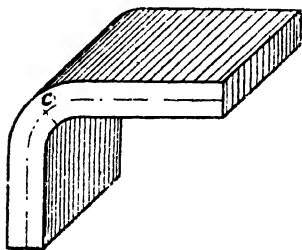


FIG. 287.

its length in the flat can be obtained by first setting out the required shape, and then measuring along the centre line of the section. To mark the plate for bending, the distance along the centre line up to C (the centre of the bend) must be measured, and this set out from the edge of the plate. In bending the mark

must be kept right in the centre of the bend.

To bend a plate with rounded corners, as in Fig. 288, the required length in the flat can be found as in the last case, or it can be calculated as follows: Suppose the inside dia-



meter to be 2 ft. and the inner radius of corners 3 in., and the plate 1 in. thick; then the radius at the corners to the centre line of plate will be  $3\frac{1}{2}$  in. And if the four quarter-circles which form the corners be added together, they will make up a complete circle of 7 in. diameter. The length of plate, therefore, to cover for the four corners will be  $7 \times 3\frac{1}{2} = 22$  in. If 3 in. be taken from each end of the inside diameter, this will leave 18 in. of flat on each side. And if  $4 \times 18 = 72$  in. be added to the 22 in., the total

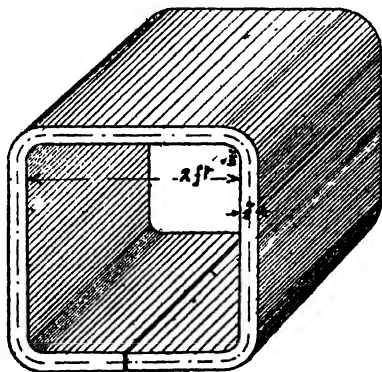


FIG 288.

length of plate will be 94 in. To mark the plate for bending, it should be remembered that the distance apart on plate of corner lines will be  $94 \div 4 = 23\frac{1}{2}$  in. If the joint is at the centre of a flat side, as shown in the figure, the marks for bending the bottom corners will be  $23\frac{1}{2} \div 2 = 11\frac{3}{4}$  from the butt edges of the plate.

In bending the plates care must be taken so that they are bent to the proper radius, or else the diameter will not come out correctly. In the workshop all kinds of methods

are in vogue to make the allowance for a rounded corner; but none are correct without they are based on the above calculations.

To centre-punch mark along the edge of a plate for flanging, the width of the flange should be set out as in Fig. 289, and the line G H measured. This will give the distance of the centre-punch marks from the edge of the plate. After being flanged, the marks should be in the position K. If a section of the flange is set out in this manner, the proper position of the rivet-hole centres can be determined for both plates.

Fig. 290 shows the plan that can be adopted to obtain the lengths of plates and pitch of rivets, where two corner plates

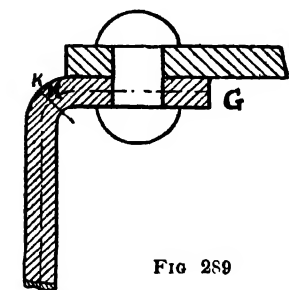


FIG 289

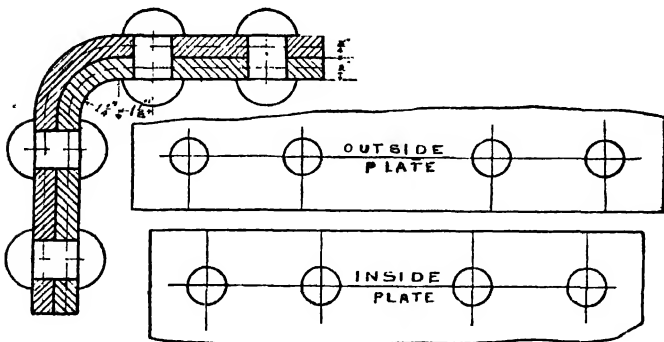


FIG. 290.

or bilge plates are jointed together. The joint is set out as shown, and the length of each plate found by measuring

along the centre line of the section. To find the pitch of rivet holes to mark on plates, the neutral lines on each plate are measured between the centre lines of the two innermost rivets. Or this pitch can be determined by calculation thus:—

Suppose the plates are  $\frac{3}{4}$  in. thick, and the inside radius of inner plate  $1\frac{1}{4}$  in., and the distance from centre of inner rivet to beginning of curve  $1\frac{1}{2}$  in. Then the length of neutral line on outside plate between the centres of inner rivets will be:—

$$2.375 \times 3.1416 + 2.25 = 5.98 \text{ in.}$$

And the corresponding length on inner plate will be:—

$$\frac{1.625 \times 3.1416}{2} + 2.25 = 4.8 \text{ in.}$$

The difference of the two thus being 1.18 in.

Where plates are bent into quarter circles, as in this case, the difference of pitch between the innermost pair of rivets can readily be worked out by the use of the following rule:—

Difference of Pitch =

$$\frac{\text{Twice the thickness of plate} \times 3.1416}{2}$$

The pitch of rivets on the flat part of the plates will, of course, be the same on both plates.

A useful application of this method of obtaining the lengths of plates or bars can be made by blacksmiths and whitesmiths. If a round, square, or flat bar is to be bent into any shape, then all that is necessary to do is to set

out the required design, as in Fig. 291, mark in the centre line, and measure for length of bar in the straight.

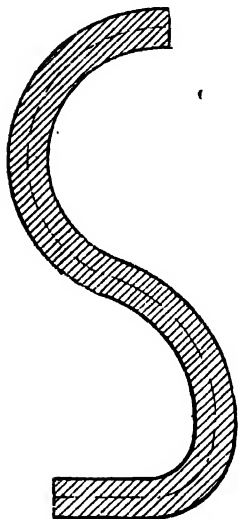


FIG. 291.

### Cylindrical Shell Plates.

In setting out plater's work for boilers or other similar class of work, a high degree of accuracy is required if joints are to be properly constructed, and the various parts made to fit together as they ought to do. The settings out for the inside and outside plates of a cylindrical shell are shown in Fig. 292. The thickness of metal is purposely drawn out of proportion to the diameter, so as to better exhibit the construction lines. The lengths of the plates can be obtained, as previously stated, by measuring the lengths of the centre lines of each ring in section and setting out for

inside and outside plates respectively. A much better plan, however, and one that will give more accurate results, is to calculate the lengths of the plates. Thus, suppose the inside diameter of inner tier of plates is 12 in. and the plates 1 in. thick, then the girth of outside plates will be:—

$$\begin{aligned}
 &15 \times 3.1416 = 47.1240 \text{ in.} \\
 \text{And inside plates } &13 \times 3.1416 = 40.8408 \text{ in.} \\
 \text{Difference in lengths} &= 6.2832 \text{ in}
 \end{aligned}$$

It should be observed that the difference in length between the inner and outer plates is  $2 \times 3.1416$ , and this

gives us a rule by which we can always determine the difference between their lengths:—

Difference = twice thickness of plate  $\times$  3.1416  
Or thickness of plate  $\times$  6.2832

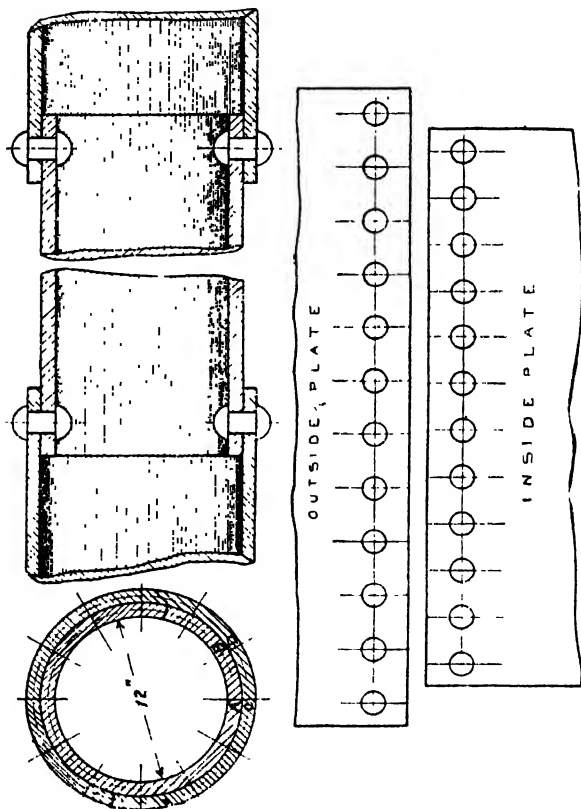


FIG. 292.

If  $3\frac{1}{4}$  be used instead of 3·1416, then this difference will always be—

$$\text{Thickness of plate} \times 6\frac{1}{2}$$

For an accurate-fitting joint, the calculation of this difference is really of more importance than the exact girths. It should be borne in mind that before proceeding to calculate, the thickness of the plate should be carefully gauged. A plate may be called a certain thickness; but as plates are usually rolled to a given weight per square foot, the thickness may be a little more or less than that stated. Consequently, if the calculations are based on a given thickness, and the plate happens to be a shade thinner, the joint will be slack, and if the plate is thicker than that allowed for, the joint will be too tight.

The pitch of the rivet-holes in the two plates can be measured directly from the centre line circles on the section of the two rings. Thus the length along the arc from A to B will be the pitch of the holes on inner plate, and the length measured along the curve from C to D will equal the pitch of holes in outer plate.

Whilst the above method is accurate enough for rough work, or for jobs bringing in only a small part of a circle, it is not of much use where very particular work is wanted. The pitch can be determined by arithmetic from the following rule—

$$\text{Pitch of holes} = \frac{\text{diameter of neutral circle} \times 3\cdot1416}{\text{number of holes in circle}}$$

Thus in the present case:—

$$\text{Pitch of holes in outer plate} = \frac{15 \times 3\cdot146}{12} = 3\cdot927 \text{ in.}$$

$$\text{Pitch of holes in inner plate} = \frac{13 \times 3\cdot1416}{12} = 3\cdot4034 \text{ in.}$$

When the distances between the hole centres run out to such awkward figures as those above, we are confronted

with a fresh difficulty in not being able to set the compasses, with exactness, to this length. So that, in practice, it is a good plan to mark the two end holes and then carefully subdivide the distance; the calculations above giving considerable aid. Usually, the centre of end holes would come on the end lines of net template; but in the present case no lap has been allowed for so as to simplify the problem. As the holes are arranged in Fig. 292, it will be observed that the distance from edge of plate to first hole will be equal to half the pitch on each plate.

The way to calculate the required pitch for any given thickness of plate, and the proper formation of the various riveted joints, will be dealt with later.

In most of the better-class boiler work the plates are rolled and the joints tacked together before drilling, the bulk of the holes being drilled in position. In this way holes with irregular walls are obviated, the joint left stronger than with punched holes, and no stresses set up in the joint. The calculations for lengths of plates and pitch of rivets will, of course, have to be carried out whether the plates have punched or drilled holes, or holes drilled after the plates are shaped and fixed.

### Tanks.

A most interesting example of a particularly simple method of jointing is that used in the construction of tanks, when the plates are flanged and lapped and no angle-iron used. Fig. 293 shows the outside view of such a tank. It will be noticed that each face of the tank has two lines of rivets upon it: hence it can be seen that the tank will be constructed of six plates, each plate having two flanges. Fig. 294 is a view of an inside corner which should readily explain the arrangement of the laps on the three plates. An outside view of the same corner is shown in Fig. 295. It will be observed from both of these views that the laps

are so formed as to leave a hole right in the corner of the tank. After the tank is riveted up along the laps, the holes at corners are either drifted or reamed out, and a special corner rivet put in as shown on Fig. 293.

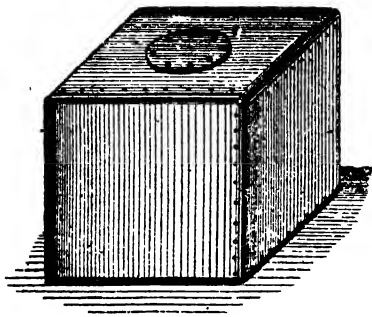


FIG. 293.

The setting out of a plate is explained by the aid of Fig. 296. A cubical-shaped tank has been chosen for the sake of simplicity. The length, breadth, and depth of the *inside* being the same, by inspection of the arrangements of the plates and joints, it will be seen that each plate is exactly the same. hence if a template be

made of one plate, the other five can be marked from it.

A section of one plate covering two joints is first set out as shown (the thickness of plate is enlarged somewhat to better show the construction lines), and from this both the length and width of plate can readily be obtained. The length of plate will be found by measuring the distance along the centre line of section, and the width will be equal to the length of flat part of plate—in this case A B. The length and breadth of plate can, of course, be calculated as in the cylindrical shell. Thus, suppose the inside dimen-

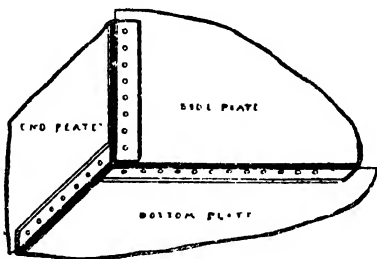


FIG 294.



sion of tank to be 4 ft., and inside radius of plate to which the flange is bent  $\frac{1}{4}$  in., thickness of plate  $\frac{1}{8}$  in., and lap  $1\frac{1}{2}$  in.

Rule for width of plate:—

“Deduct twice the thickness of plate and twice the inside radius of flange from the inside dimension of tank.”

$$\text{Width} = 48 - 2\left(\frac{1}{4} + \frac{1}{8}\right) = 48 - \frac{3}{4} = 47\frac{1}{4} \text{ in.}$$

Rule for length of plate:—

“To the width of plate add  $3\frac{1}{2}$  times the radius of centre line and twice the lap.”

$$\text{Length} = 47\frac{1}{4} + \frac{5}{16} \times 3\frac{1}{2} + 1\frac{1}{8} \times 2 = 50\frac{7}{8} = 50\frac{1}{2} \text{ in. (nearly).}$$

There should be no difficulty in marking out the holes on plates, as each line of holes is exactly the same. A good

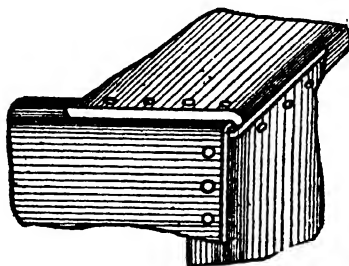


FIG. 295.

method to pursue is to make a template of hoop iron or a batten of timber, with a line of holes carefully set along at the required pitch. From this, all the holes can be marked, and it will avoid the lifting about of a heavy template, which would happen if one of the plates were used for this purpose.

All rivet-holes can of course be punched before the plates are flanged. The gauge for marking the width of flange

from edge of plate will be the distance measured along the centre line of section from the end of plate to middle of bend. It can also be calculated by the following rule: "To the lap add one-quarter of  $3\frac{1}{2}$  times the radius of centre line of section."

Width of flange—

$$= 1\frac{1}{8} + \frac{5}{16} \times 3\frac{1}{2} \times \frac{1}{4} = 1\frac{89}{224} = 1\frac{3}{8} \text{ in. (nearly).}$$

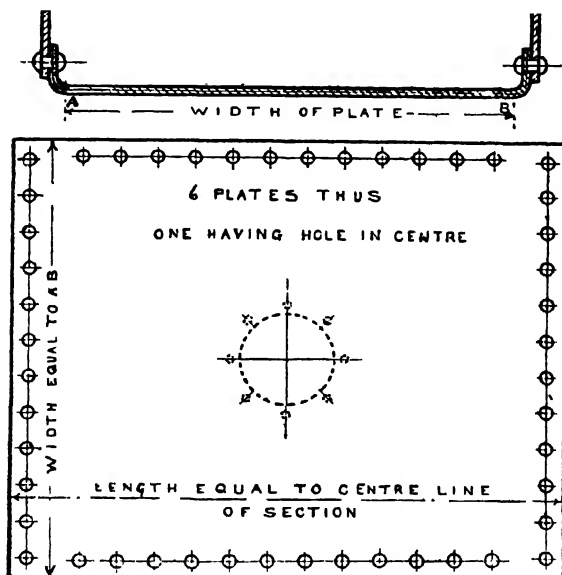


FIG. 296.

The cover is bolted on with set screws, and the holes for these are drilled and tapped to suit the screws.

Whilst a cubical tank has been described, the above remarks and calculations can of course be easily modified and applied to suit the case of any sized tank with either open or closed top.

## CHAPTER XXXIII.

## PLATER'S DOUBLE-CURVATURE WORK.

DOUBLE-CURVED work in wrought iron or steel plates is, of course, much more difficult to manipulate than in the softer metals, and, on account of the greater resistance that iron or steel offers to being drawn or stretched, greater accuracy is, in consequence, required in the marking out of the plate shapes. At the best, it is only possible to approximate to the real shape of plate wanted, and, in any case, theory is not of much use in this class of work, without it is tempered with experience. Another point to remember is that the amount of stretch or contraction in any particular plate depends very much upon its treatment in working into shape. In all cases it should be aimed to hollow or raise a plate in a natural manner—that is, to work it up as near as possible to the conditions that would obtain if it were stamped or drawn in a pair of dies. We purpose giving one or two typical cases of this class of work, beginning with a

**Curved Pipe-Bend.**

A sketch of the bend is shown in Fig. 297, on which it will be seen that the back and throat of the curved portion is made up in two pieces, and the cheeks in three; the joints being broken as shown.

The construction lines for the templates are obtained as shown in Fig. 298. An elevation of a segment is first set out; this really showing the elevation of the pieces com-

bined. A semicircle is described on 0 8 and divided into eight equal parts, lines square to 0 8 being run down from each division point. Then, with C as centre, arcs are run around from the foot of each perpendicular, as shown. The complete circumference of the pipe is divided into four equal

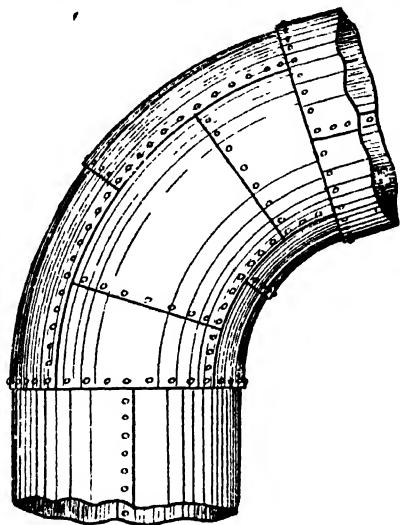


FIG. 297.

parts by the longitudinal joints: hence the length of the girth line for each pattern will be equal to four divisions from the semicircle. To deal with the back pattern first. The girth line of four equal divisions is laid down, and cross lines drawn as shown, these latter being cut off equal in length to the correspondingly-numbered arc in the elevation. Thus 0 0° on the pattern equals 0 0" in the elevation, 1 1° equals 1" 1', and 2 2° equals 2" 2'. In working the plate into shape it will be found that the line 0° 0° lengthens slightly, and that the edge 2° 2° will shorten a little; hence,

as it will manifestly be an advantage to be on the safe side, the best plan will be to draw the arc  $2^0 0^0 2^0$  to pass through the point  $0^0$ , as first found, and make it somewhat flatter

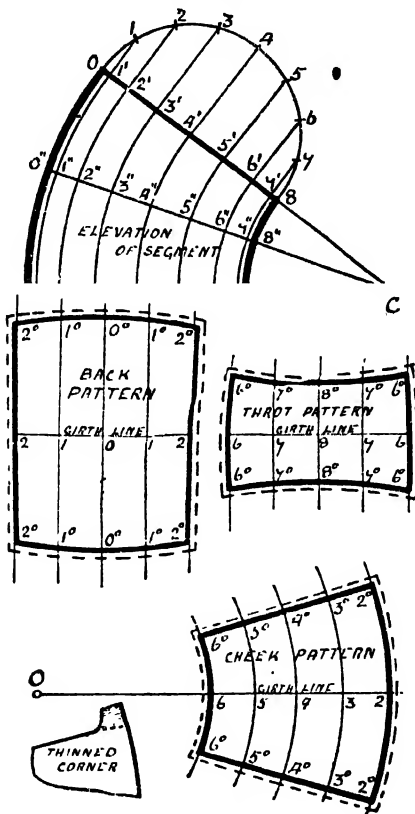


FIG. 298.

than is necessary for it to run through the points numbered  $2^0$ . In this way the edge line  $2^0 2^0$  will be made slightly

longer.<sup>1</sup> As the joints are lapped, the bottom end of the pattern will require to be made just a shade narrower than the top; this can be allowed for by deducting one and a half times the plate thickness from the width.

The throat pattern can be laid out in a similar manner to the back, and here it may be seen that the centre line will shorten slightly in working the plate into shape, and the side lines lengthen somewhat. This difference can be allowed for by making the end arcs  $6^{\circ} 8' 6''$ , to pass through the points  $6^{\circ} 6'$ , as first found, and slightly flatter than required to pass through the original position of the point  $8^{\circ}$ . Here again the pattern must be one and a half times the plate thickness narrower at one end than the other. It will also be an advantage to slightly curve the side edges, as shown on the pattern.

The shape of the plate for the cheek can be laid out by first making the radius O 4 on the pattern equal to C 4" on the elevation; then on each side of the point 4 setting two lengths from the semicircle, to make up the girth line, 6 2. Now, using O as centre, arcs are drawn through each point on the girth line as shown, these being cut off respectively equal in length to the corresponding arc in the elevation. Thus  $4^{\circ} 4'$  equals  $4'' 4'$ ,  $3^{\circ} 3'$  equals  $3'' 3'$ , and so on for the others. It will be found that the points  $2^{\circ}$  to  $6^{\circ}$  lie practically on a straight line, hence this can be drawn in as seen. For a bend of a very sharp curvature it will be an advantage to lengthen the arc  $2^{\circ} 2'$  just a little, as this will contract somewhat in bringing the plate into shape. Allowance for joints will be added, as shown by the dotted lines.

If instead of making the throat portion in two plates, as shown in Fig. 297, it is desired to make it out of one plate, then the curves at the plate-ends will be somewhat flatter than shown on the throat pattern, as the draw will be less, on account of the longer plate.

In work of this description it is not advisable, only under exceptional circumstances, to put any holes in the plates until after they are shaped. If there are many bends a "cradle"

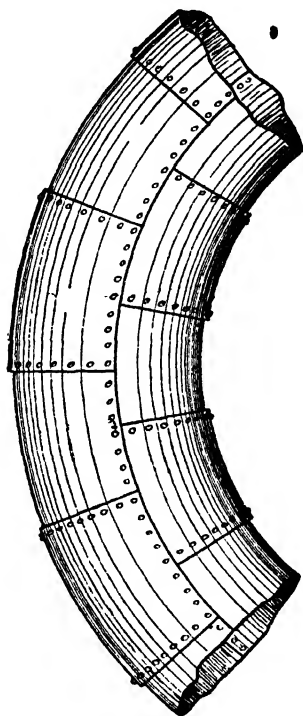


FIG. 299.

punching template for each plate might then very conveniently be made for marking the joint holes.

Instead of having four plates to make up the complete

girth of the pipe, as in Fig. 297, two plates may be used, as in the

### Furnace Blast Pipe,

part of which is shown in Fig. 299. Here it will be seen that the longitudinal joints run around the middle of each

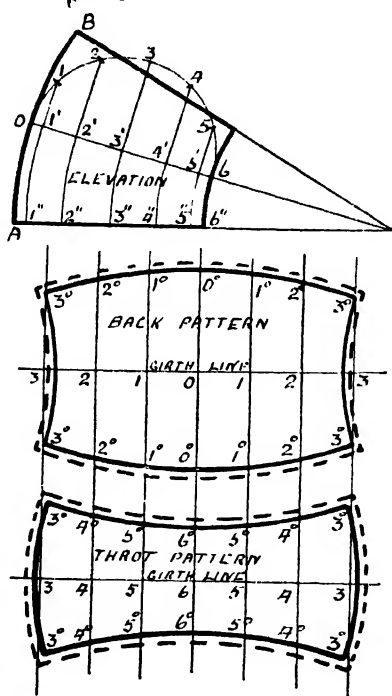


FIG. 300.

side of the pipe, while the transverse joints come to the middle of opposite plates.

The patterns are shown set out in Fig. 300. An elevation of a segment is first drawn, the arc A B being made equal



to the width of a segment between the centre lines of the rivets on the back of the pipe-bend. The radius  $O C$ , of course, represents the radius of curvature of the back of the bend. A semicircle is constructed upon  $O 6$ , and divided into six equal parts, perpendiculars from each division point then being run down, as shown. The girth line, 3 3, of the back pattern will be laid out equal in

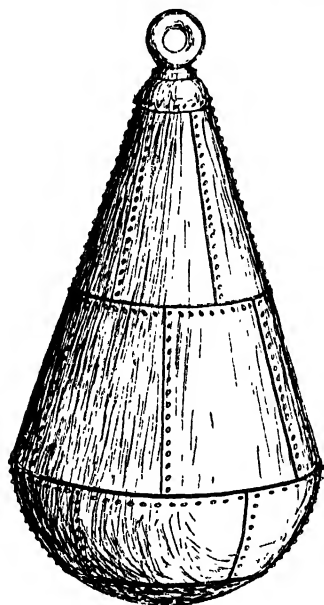


FIG 301.

length to the semicircle and divided into six equal parts, cross lines being run through each division point. These construction lines are then cut off the same length as the similarly-numbered arcs in the elevation. Thus  $3\ 3^0$  equals  $3'\ 3''$ ,  $2\ 2^0$  equals  $2'\ 2''$ , and so on for the remaining lines.

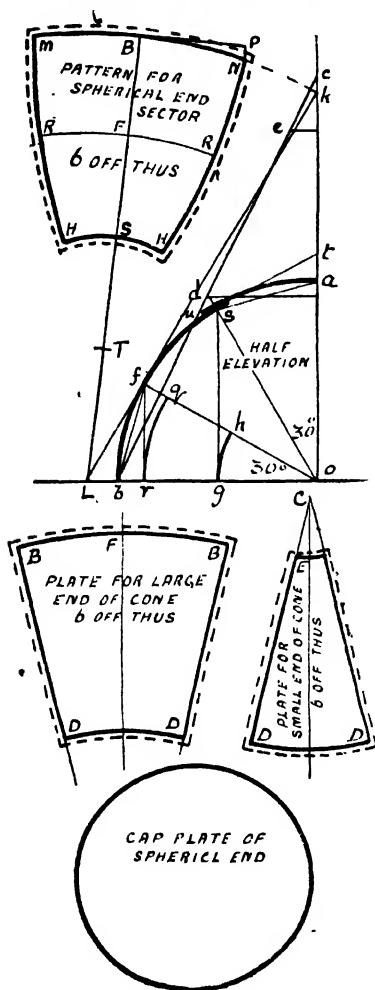


FIG. 302.

In working the plate up it will be found that the line  $0^0 0^0$  will lengthen somewhat: hence it will be an advantage to make the arc  $3^0 0^0 3^0$  slightly flatter than would be required to pass through the position of  $3^0$  as obtained by using the length of the arc  $3' 3''$ . Instead of being left straight, as in Fig. 298, it will be an advantage to curve the side edges as shown, the radius used being slightly longer than  $C 3'$ . As the girth line  $3 3$  on the back pattern will lengthen in hollowing, the side curves should be drawn to pass through the points  $3^0 3^0$ , in this manner shortening the line  $3 3$  somewhat.

The pattern for the throat segment can be struck out in a similar manner to the back, the lines used being those having corresponding numbers on pattern and elevation. Here, again,

it will be an advantage to curve the side edges to  $\frac{1}{2}$  radius slightly greater than the centre radius, C 3', in the elevation.

As the curves at the ends of the patterns come out practically as arcs of circles, there is really no necessity to use all the lines as shown. All that is wanted being the points  $3^0$ ,  $0^0$ ,  $3^0$  on the back pattern, and  $3^0$ ,  $6^0$ ,  $3^0$  on the throat pattern. The lengths of lines to obtain these can also be calculated if required, and thus the necessity of drawing any kind of elevation avoided. In ordinary practice, however, it is generally the safer plan to use an elevation for obtaining lengths of construction lines.

In working the plates hot, care must be taken that they are drawn or hollowed as uniformly as possible, as the plates, if worked too much in any one particular part, will be pulled out of the shape that the pattern has been designed to produce.

As the plate segments are arranged to fit alternately outside and inside, it is evident from what has been said previously that the girth of the outside plate must be  $3\frac{1}{4}$  times the thickness longer than that of the inside plate. It will also be necessary to thin the four corners of the inner plates on the back and the four corners of the outer plates of the throat. A sketch of the method of thinning is shown at the bottom of Fig. 298.

### Patterns for Buoy-Plates.

We may consider the buoy, shown in Fig. 301, as being constructed of a cone and a hemisphere. It will be seen from the position of the joints that the girth of the buoy is divided up into six plates.

Four patterns will be required, and these are all shown set out in Fig. 302. The patterns for the conical part will be laid out as explained in the earlier chapters; the radii

for the bottom tier of plates being  $c b$  and  $c d$ , and for the top tier  $c d$  and  $c e$ . The arc  $B F$  on the large plate will equal in length the arc  $b f$ , this being one-twelfth the circumference of the cone base. The length of the arcs, marked  $D D$ , at the small end of the large pattern, and the large end of the small pattern, should be the same length; or, if the thickness be taken into account (which it always should),

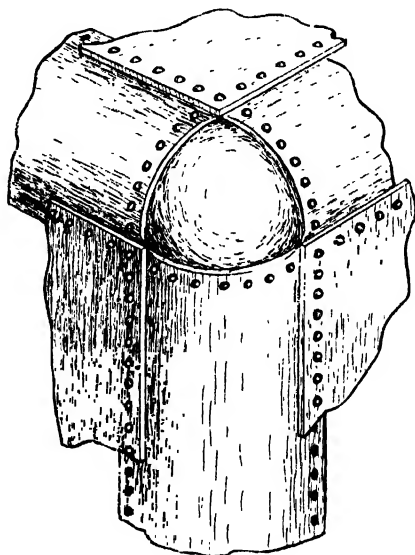


FIG. 303.

the arc  $D D$  on the small pattern—seeing this plate is one of the inner tier—will be the thickness of the plate less in length than on the large pattern. Two corners on each of these plates will need thinning, and, of course, the rivet-holes can be put in before the plates are rolled.

The hemisphere is made up in seven pieces: six sectors and a circular centre plate. First let us mark out the shape of plate for one of the gores, or sectors. A quarter-circle,  $b o a$ , is drawn, and the lines  $o f$ ,  $o s$  set along to make angles of  $30^\circ$  with  $o b$  and  $o a$  respectively; the arc  $b s$  will then give one-sixth the circumference of the hemisphere. Next draw  $L k$  square to  $o f$ , and, using  $L$  as centre, run around the arc  $k M$ . Now lay down the line  $L B$  in any convenient position, and draw  $B P$  square to it, and equal in length to the arc  $f b$ ; then run down  $P N$  parallel to  $B L$ , cutting the arc  $k M$  in  $N$ . Next mark  $B M$  equal to  $B N$ . The points  $F$ ,  $S$ , and  $T$  are then determined by making  $B F$  equal to the chord  $b f$ ,  $F S$  equal in length to the arc  $f s$ , and  $S T$  equal to  $s t$ ; the latter line being drawn square to  $o s$ . Using  $T$  as centre, and  $T S$  as radius, an arc is now drawn through  $S$  and cut off equal in length, on each side of  $S$ , to the arc  $g h$ ; that is,  $S H$  equals  $g h$ . The point  $g$ , it will be noticed, is determined by dropping a perpendicular from  $s$  on to the line  $o b$ . The line  $f r$  is next drawn square to  $o b$ , and the arc  $r q$  run around. Now, using  $L$  as centre and  $L F$  as radius, the arc  $R R$  is drawn, the lengths  $F R$  on each side being measured off equal in length to the arc,  $r q$ . Choosing a suitable radius (one that will give an arc to pass through the points  $H$ ,  $R$ ,  $M$ ) the side curves are now drawn. Allowances for laps are afterwards added as shown.

In work of this character, where the operator has had little experience, it is always best to experiment on a model pattern, this being marked out for a similar article drawn to a small scale. Such a pattern is shown marked out at the bottom of Fig. 304. The model pattern can be cut out of sheet iron or other metal, and before working into shape, its surface should be firmly marked with crossed lines, as shown, these being  $\frac{1}{8}$  in. or  $\frac{1}{4}$  in. apart. When this pattern has been worked up to the proper curvature, it can then be examined, and by measuring between the lines on its

surface it can be ascertained which part has been extended or contracted. If it does not work up to the exact size re-

quired, then, by careful examination and measurement, the deficiency can be determined, and this allowed for when striking out the pattern for the full-size articles.

The dimension of disc for the spherical segment will be found by using  $au$  as the radius to mark it out.

By the exercise of some thought and careful experiment the pattern for any other kind of gore for an egg-ended boiler, still, or other vessel can be struck out with a good degree of approximation.

### Rounded Corner for Tank.

A rounded corner-plate for a tank, motor-car hood, or

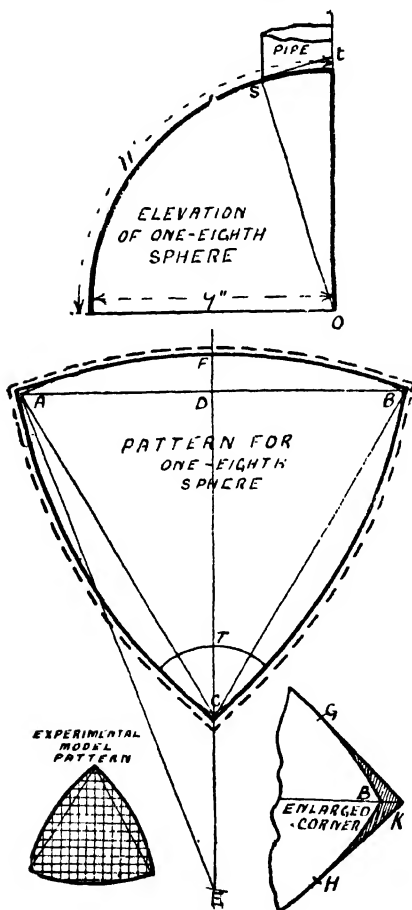


FIG. 304.

other object can be set out in the flat very much the same as explained in connection with Fig. 302. A sketch of the corner-plate is shown in Fig. 303, and, on consideration, it will be seen that its surface can be imagined to be that of one-eighth of a complete sphere. In practical plate work it would, of course, be an advantage to break the joints somewhat differently to that shown in the sketch; but this example, as the joints are arranged, will serve to illustrate the setting out of patterns for objects that come out as a part of a spherical surface.

In Fig. 304 the necessary setting-out required for the pattern for one-eighth of a sphere of 14 in. diameter is shown. The circumference of a 14 in. sphere will be 44 in., one quarter of this, of course, being 11 in. First construct an equilateral triangle of 11 in. side, lettered A B C, in the figure. It is found from experiment that the radius giving the best curve for the sides of the pattern is  $2\frac{1}{2}$  times the radius of the sphere, which in this case will be—

$$2\frac{1}{2} \text{ in.} \times 7 \text{ in.} = 15\frac{3}{4} \text{ in.}$$

Bisect A B in D, and join to C, producing the line D C outwards. Now, using A as centre and  $15\frac{3}{4}$  in. as radius, mark the point E. This will give the centre from which the arc, A F B, can be described. In the same way the other two arcs can be constructed. A set-square should now be put upon each corner, and two tangential lines, mutually perpendicular, drawn from the arcs. This is best shown by the enlarged corner at the bottom of Fig. 304. Here B G and B H represent the side arcs, and K G, K H the pair of mutually-square lines. It will thus be seen that the small shaded area is added on to the pattern to make it work up correctly. Allowance for laps will be added as shown.

As mentioned in the last example, it is always advisable for the inexperienced in this kind of work to make up a

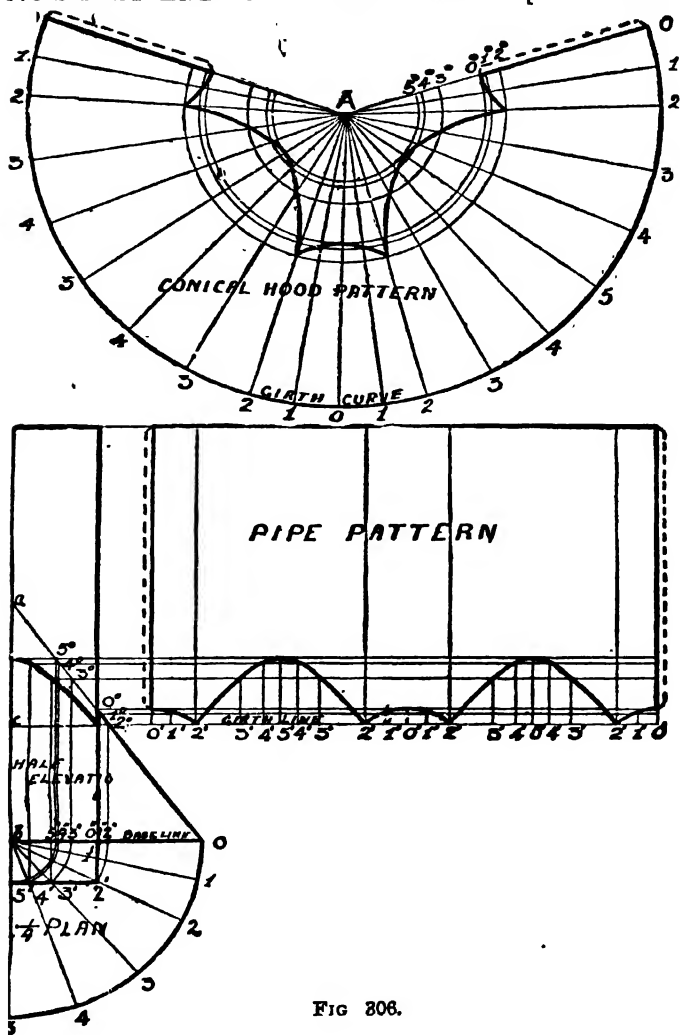


FIG 306.



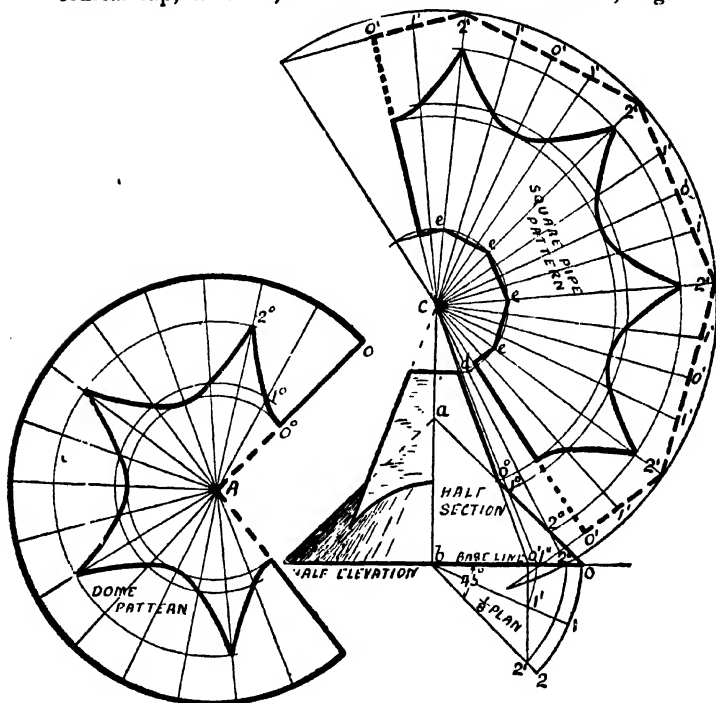
The point *b* is joined to 2', and produced outwards to 2; the arc 2 0 then being divided into two equal parts and the arc 2 5 into three equal parts. The division points, 1, 2, 3, etc., are then joined to *b*, thus fixing the points 1', 2', 3', etc. Taking *b* as centre, and *b* 5', *b* 4', etc., respectively, as radii, the points 5', 4', etc., are turned on to the base line, thus giving the points 5'', 4'', etc. Perpendiculars are then run up from the latter points to meet the outside lines of the curve in 0°, 1°, 2°, etc. A girth line is then laid out for the rectangular pipe pattern by marking the distances 0' 1', 1' 2', 2' 3', etc., as taken from the same numbered line in the plan. Perpendiculars are next run up from the girth line division points, and these cut off by projecting along the required heights from the elevation. That is, a line is drawn along through 5° to cut off all the perpendiculars drawn up through the points marked 5' on the girth line; the same for 4°, and so on for each number. (In practice it will be better to mark out the pipe pattern away from the elevation, the heights for these lines then being measured from the line *c* 2° up to the respective points.) The points as found are then joined up, and the rectangular pipe pattern is complete.

The pattern for the conical part can be struck out by first setting the compasses to *a* 0 as radius, and describing the pattern circle. The length of the girth curve can be measured out by making the respective lengths the same as those with the similar number on the quarter-plan. The division points of the girth curve are then all joined up to the centre, *A*. To mark off the points on the radial lines, to form the cut, the compasses are opened out to *a* 5°, *a* 4°, etc., on the elevation, and these distances used to mark around the arcs on the pattern. Thus, *A* 5° on the pattern equals *a* 5° on the elevation, and so on for the other lengths. Where these arcs cut the correspondingly numbered radial lines will give points on the pattern

cut as shown. These being joined up with an even curve will complete the pattern. Any allowance for laps can be added according to the method of jointing adopted.

### **Tapered Square Pipe Fitting on Conical Dome.**

A tapered square pipe fitting concentrically on to a conical cap, or dome, as shown in the half-elevation, Fig.



**FIG. 307.**

307, may for some kinds of ventilator, or other work, require to be made up in sheet metal.

All the setting out necessary to obtain the pattern con-

struction lines can be done with a one-eighth plan and a half-section, as shown in Fig. 307. On the plan,  $b$   $O'$  and  $O' 2'$  each equal half the diameter of the base of the pyramid. The centre,  $b$ , is joined to  $2'$  and produced outwards to meet the cone base in  $2$ , the arc,  $2 O$ , then being bisected and the middle point,  $1$ , joined to  $b$ . The points  $2'$  and  $1'$  are now swung up, around  $b$ , on to the base line, giving the points  $1''$  and  $2''$ . These latter are then joined to  $c$ , and where the connecting lines cut the outside of cone in  $O^0$ ,  $1^0$ , and  $2^0$  will determine the lengths required for the two patterns.

In marking the pattern out for the tapered square pipe, the compasses are put in centre  $c$  and opened to the point  $2''$ , the outer arc then being described to this radius. The compasses are next set to the length of the side of the pyramid base, that is, twice the length of the line  $O' 2'$  on the plan, and *five* lengths to this stepped around the arc on the pattern, thus marking the points  $2'$ . The five chords are next drawn by joining the points marked  $2'$ , the two end chords being bisected in the points  $O'$ . It will thus be seen that there are three full sides and two halves to make up the complete pattern of four sides. The points  $1'$  and  $O'$  on the pattern are fixed by making the lengths of  $2' 1'$  and  $2' O'$  the same as these lines on the plan. From each point radial lines are drawn to  $c$ , these being cut, to give points on the pattern curve, by drawing arcs around from the points  $O^0$ ,  $1^0$ , and  $2^0$ . Thus, to give one instance, where the arc drawn from  $1^0$  intersects the radial lines  $1' c$ , will give points on the curve of the pattern cut. These are then all joined up with even curves, as shown. The cut to form the small end of the pipe is set out by producing the top line in the elevation outwards to meet  $c 2''$  in  $d$ ; then, with  $c d$  as radius, the arc is swept around, and where this intersects the lines  $c 2'$ , in  $e$ , on the pattern, will give the end of the top lines; these being then drawn in, as shown, by the lines marked  $e e$ .

The outer dotted pattern, it might be useful to remember, will, if bent into shape, give the portion of the tapered square pipe which fits *inside* the conical dome.

For the conical dome pattern the compasses are set to the radius  $a\ 0$  in the elevation, and the circular arc marked out; sixteen distances being stepped around this, each equal in length to either of the arcs  $0\ 1$  or  $1\ 2$  in the plan. From each division point radial lines are drawn to the centre  $A$ ; these are then cut by arcs drawn to the respective radii,  $a\ 0^\circ$ ,  $a\ 1^\circ$ ,  $a\ 2^\circ$ , from the half-section. Thus the length  $A\ 1^\circ$  on the pattern equals  $a\ 1^\circ$  on the section, and so on for the other lines. The points being joined with even curves, the pattern is now complete.

It is interesting to notice that the inner pattern, marked off by the dotted line  $A\ 0^\circ$ , will, when bent into shape, give the portion on the cone fitting *inside* the tapered square pipe.

If the centre lines of the pyramid and cone do not coincide, the patterns for the parts required can still be marked out by the method shown above, the only difference being in the plan, this, perhaps, requiring to be a half or a full-size plan, according to the position of the tapered square pipe on the dome.

### Round Pipe on Conical Cap.

If a cylindrical pipe fits on to a conical pipe, both having the same centre line, it will be manifest that the cylindrical pipe will be cut square at the joint, and that the conical pipe will come out as a frustum of a cone. If, however, their centre lines do not coincide, but are some distance apart, and parallel, the two pipes will fit together as shown in Fig. 308.

Before attempting to mark out the pattern it will be necessary to first draw in the elevation of a joint curve. To do this, construct the semicircle, as seen in plan, Fig. 308,

and divide it into six equal parts, running lines up through each division point square to the base line. Now, taking  $b$  as centre, and  $b\ 1$ ,  $b\ 2$ , etc., as radii, swing on to the base line, thus determining the points  $1'\ 2'$ , etc. From these

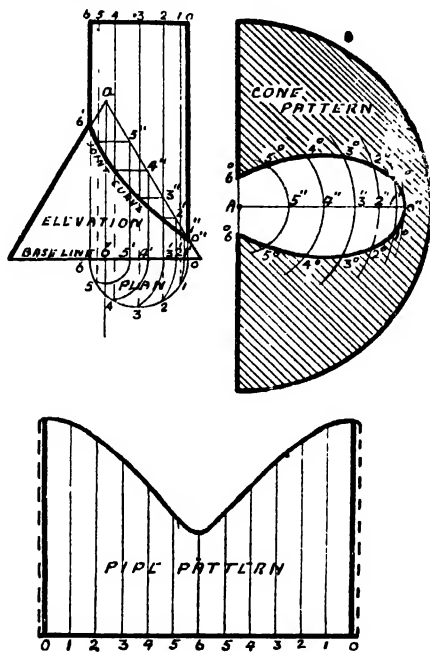


FIG. 308.

last points run perpendiculars up to intersect the outside lines of the cone in  $0'', 1'', 2''$ , etc., and then from these draw lines across parallel to the base line to meet the perpendiculars already drawn from the points on the semicircle. The points of intersection of these two lines will lie on the joint curve.

The complete conical pattern is first marked out in the

usual way, and a centre line,  $A\ 0''$ , drawn. Along this the distances from  $a\ 0''$  in the elevation are set; that is,  $A\ 5''$  equals  $a\ 5''$ ,  $A\ 4''$  equals  $a\ 4''$ , and so on. With  $A$  as centre, arcs are then drawn through the points  $5''$ ,  $4''$ , etc. The lengths of these are carefully measured off equal to that of the corresponding arc on the semicircle in plan. Thus  $1''\ 1^\circ$  equals  $1\ 1'$ , the arc  $2''\ 2^\circ$  is the same length as  $2\ 2'$ , and so on for the others. The points so found when joined up with an even curve will give the cut required.

For the cylindrical pipe the pattern will be marked out in the usual way, the lengths of the construction lines being measured from the top end down to the joint curve.

### Circular Tapered Pipe Fitting on Conical Dome.

If the centre lines of these two conical surfaces coincide, it is evident that each part will come out as a frustum of

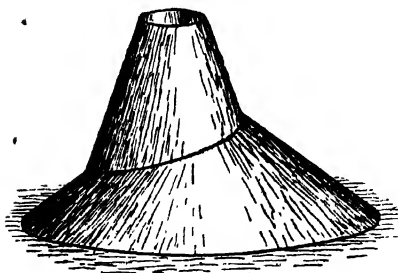


FIG 309.

a cone; but if the centre lines are not common to each, but parallel, then the two parts will fit together as shown in Fig. 309.

In the latter case the problem becomes somewhat more difficult.

The setting out of the patterns is shown in

Fig. 310. Just as in most other cases that we have dealt with, the first thing to be done is to obtain an elevation of the joint curve. For this purpose an elevation and half-plan of the dome and pipe is constructed. Through the points  $0''$  and  $6''$  lines parallel to the base line are drawn, cutting the centre line of the large cone in the points  $e$

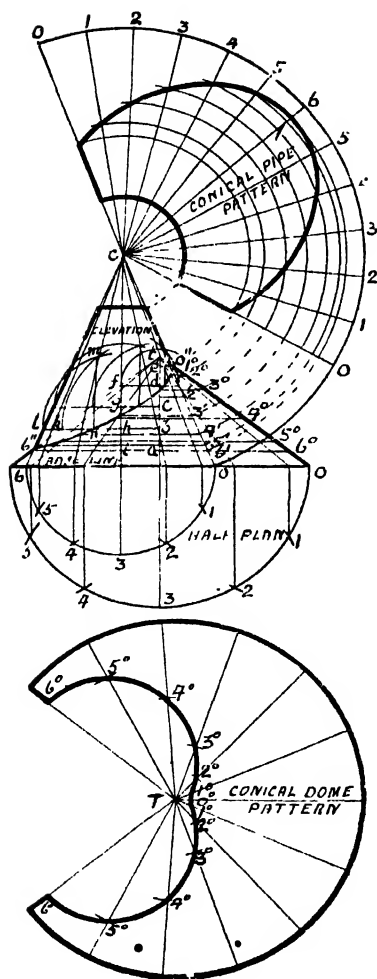


FIG 310.

and *a*. Then the line *ea* is divided into, say, four equal parts, giving points *b*, *c*, and *d*. Cross lines are then drawn through each of these points to cut the centre line of the small cone in *f*, *g*, *h*, and *i*. Now taking *b* as centre, and *bc* as radius, draw an arc of a circle; then, with *h* as centre, and *hi* as radius, construct another arc to cut the former in *m*. From *m* drop a perpendicular on to *bc*, thus obtaining *n*, which will be a point on the joint curve. In the same manner, circular arcs can be described on the lines passing through *c* and *d*, and further points on the joint curve obtained. These being carefully joined up will give the elevation of the joint curve as required for getting the lengths of the pattern construction lines.

For the conical pipe pattern it will be most convenient to produce

the sides down to the base line, and on this describe a semicircle, dividing it into six equal parts, as shown. Perpendiculars are then run up from each division point to the base and joined to the apex,  $c$ , of the cone. Where these radial lines cross the joint curve, lines square to the centre line are run to the outside of the cone, giving the points  $5'$ ,  $4'$ ,  $3'$ , etc. The lengths  $c 5'$ ,  $c 4'$ , etc., are then transferred by running the arcs around on to the correspondingly numbered radial line of the complete cone pattern, thus giving points for the pattern cut. These being connected with a fair curve will give the required pattern cut for the conical pipe.

In the same manner the pattern for the conical dome can be struck out. The semicircle in plan is divided as before, perpendiculars run up, and radial lines drawn. From the points where these latter intersect the joint curve, cross lines are drawn to meet the outside line of the conical dome in the points  $5^\circ$ ,  $4^\circ$ ,  $3^\circ$ , etc. Then for the pattern, these lengths are marked off on the construction lines. That is  $T 5^\circ$ ,  $T 4^\circ$ , etc., on the pattern will respectively equal  $t 5^\circ$ ,  $t 4^\circ$ , etc., on the elevation. Any laps for jointing can, of course, be added as required for either of the patterns.

### Round Pipe with Spiral Joint.

If a pipe is required to have a twisted seam as shown in Fig. 311, the rake of the pattern strip can be quite easily determined by the method of construction as seen in the figure. The pipe girth is laid out first and the line  $A B$  drawn perpendicular and made equal in length to the height of half a twist. Line  $B C$  is then marked off equal to half the pipe circumference, and the pattern completed as shown.

If  $A B$  had been made equal to the pitch of the spiral seam—that is, the vertical height of one complete twist—



then B C would have to be made equal to the complete pipe girth.

### Sheet Metal Worm.

Sheet metal screws for moving grain along a trough, as shown fitted to a shaft in Fig. 312, are usually made up out of rings which are shaped by hammering and riveted together. Being a twisted surface it is not strictly developable, but a very good approximation can be obtained by the diagram shown in Fig. 312. A C is set out equal to the shaft circumference, and A B made the same height as the pitch; the

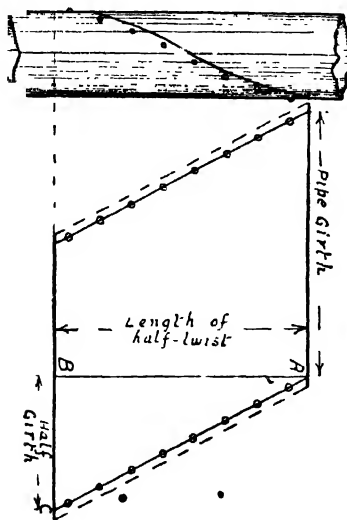


FIG. 311.

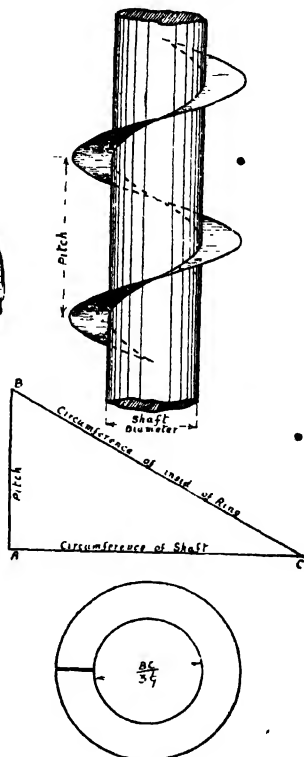


FIG. 312.

line B C will then give the length of the inner circumference of the pattern ring; the corresponding diameter being determined by dividing B C by  $3\frac{1}{2}$ .

By calculation it can be shown that the outside of the ring is a little longer than that required for the outside of the spiral, but when the pitch is small and the ring narrow the difference is very slight. To give the twist without buckle the rings will require to be carefully hammered, the blows falling heaviest on the inner part of the ring.

### Twisted Rectangular Pipe Bend.

A peculiar application of the last case can be made to that of an oblong pipe bend, as shown in Fig. 313. In this the top and bottom pieces will be formed by a quarter of a ring as explained in connection with Fig. 312. The side

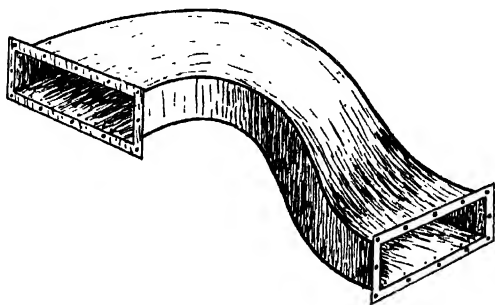


FIG. 313.

strips will be straight, with the ends just curved to cant the bend to meet the straight lines of pipes.

The patterns are shown marked out in Fig. 314. For the inside and outside patterns the heights B E and D F will respectively equal the difference in level of the two lines of piping—that is, it will correspond to a quarter of the

pitch, as shown in Fig. 312.  $AB$  will equal the girth  $ab$ , and  $CD$  that of  $cd$ . The distance  $FC$  will give the length of the quarter-circle  $SS$ , and from this the radius  $OS$  can be calculated, and the pattern thus set out.

### Junction of Straight and Bent Round Pipes.

If a straight pipe is to fit on to a curved bend, as shown in Fig. 315, it will be necessary to obtain the shape of the joint line before the pattern can be set out. This is very simply done by describing the semicircles, as seen on the figure; dividing up in the same manner, then running lines down and arcs around from centre  $C$  to intersect; thus giving points on the joint curve. The pattern (not shown) will then of course be set out in the usual way.

Any other junction of a straight with a curved pipe, either of the same or unequal diameters, can be marked out in a similar manner.

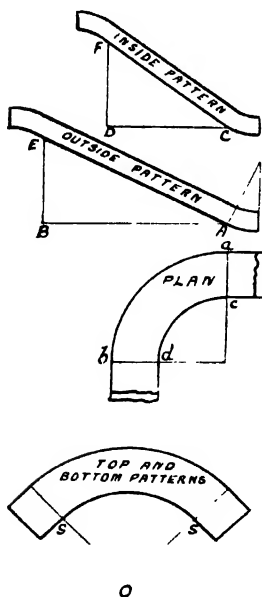


FIG. 314.

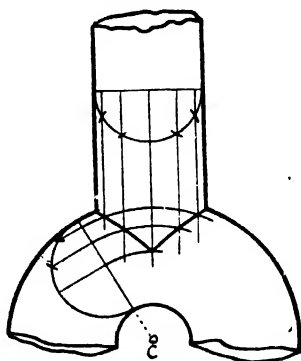


FIG 315.

### Oblique Square Connecting Pipe.

When two square pipes, having their ends cut level, need connecting, this may be accomplished by joining them with an oblique square pipe, as shown in Fig. 316.

The setting out of the pattern is obviously so simple that there is no need for further description.

In bending up it should be remembered that the *ends*

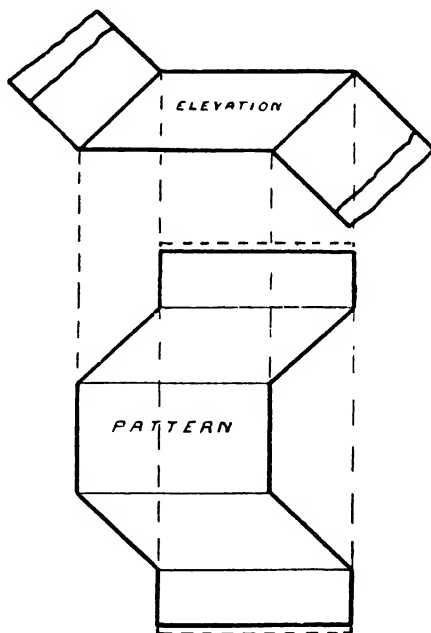


FIG. 316.

of the connecting pipe will be square, its cross section, of course, being rectangular.

### Tapered Oblique Square Connecting Pipe.

In a similar manner to the previous case, when two square pipes of unequal sizes require connecting, the intermediate pipe will come out as a frustum of an oblique square pyramid, as shown in Fig. 317.

For the pattern B D will be drawn perpendicular to C B

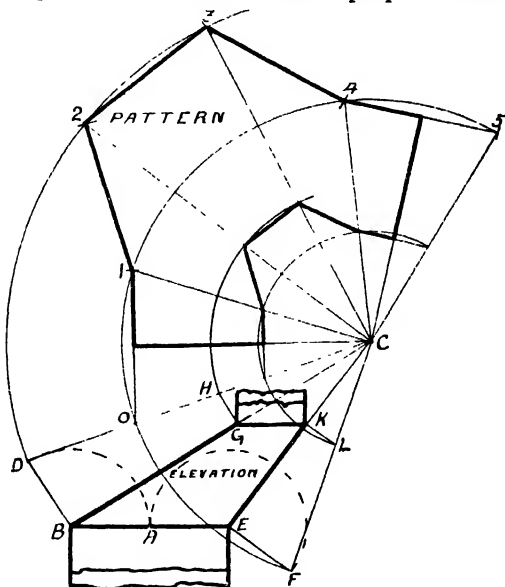


FIG. 317.

and equal in length to B A ; D then being joined to C and H G drawn square to B G. In the same way points F and L can be determined. Now using C as centre, arcs are swept around from points D, F, H, and L. Then commencing, say, at 0 the distances 0 1, 1 2, etc., each equal to B E, are marked off. The remaining part of the work should require no further description.

**Square Hopper for Outlet on Round Pipe.**

The setting out shown in Fig. 318 is for an outlet fitting on the underside of a pipe, but the method of laying out the pattern will be exactly the same if the case is that of a hopper resting on top of the pipe.

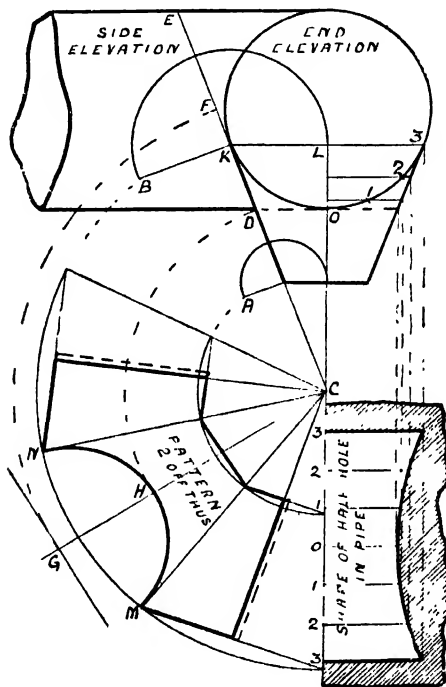


FIG. 318.

Geometrically this is the intersection of a pyramid and a cylinder.

In striking out the patterns the point B is obtained by

drawing the line B K square to K C, and making it equal to K L, the point A being fixed in a similar manner. Now, using C as centre and C B as radius an arc is swung around, and on this three full widths each equal to K 3 cut off. The two outside lengths are each bisected, as it will be seen that the pattern is for making the article up in two pieces. The curve passing through H on the pattern can be set out by first getting the middle point F of D E and then cutting C G off equal to C F; fixing H by making C H equal to C D; drawing a line through G at right angles to G C, and by the trammel method (Chapter XXI.) constructing the part ellipse M H N. The major axis of the ellipse will, of course, be E D, and the minor axis the diameter of the pipe.

The hole is shown marked out by projection; the girth being measured from the end elevation along the arc 0 to 3. It could manifestly be set out in any position, the lengths of construction lines being taken by measurement across the circle in the end elevation.

### Spherical Surface Dome in Sectors.

A flat dome like a gasholder top (Fig. 319) can have the patterns for its sectors struck out by assuming that each ring or tier of plates forms part of a cone surface. Thus a pattern for the outer ring in Fig. 319 will be laid out by

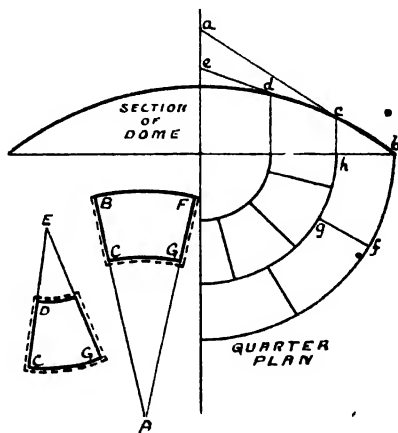


FIG 319.

making radius  $A B$  equal to  $a b$ ;  $A C$  equal to  $a c$ , and the length  $B F$  equal to  $b f$ . In the same way the next tier of plates can be dealt with.

A dome pattern of this character can also be made up by the strip method, as shown in the chapters on roofing work.

### Cylindrical Pipe on Spherical Dome.

A pipe fitting as above is shown in Fig. 320. Before its pattern can be developed a series of points on the elevation of the joint line will have to be determined. As the method of finding each point is the same the construction for one

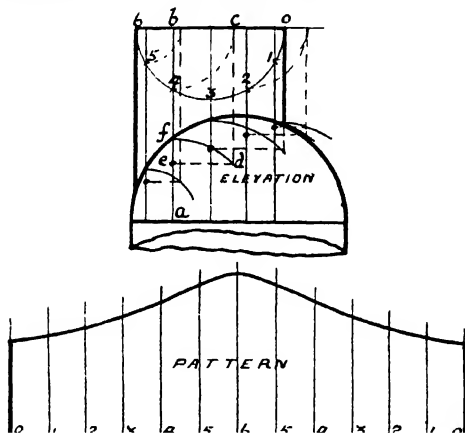


FIG. 320.

point only (4) is shown. With centre  $a$  and radius  $a f$  describe the arc  $f d$  of indefinite length, then with centre  $b$  and radius  $b f$  describe the arc  $f c$ . From  $c$  run down a perpendicular to meet the arc in  $d$ ; and to fix  $e$  run a line square across from  $d$ .

Having determined all the joint line points the pattern can be set out in the usual way.



### Conical Spout Fitting on Conical Vessel.

Perhaps the most complicated patterns to mark out are those for objects where the two parts fitting together are both conical. Such a case is shown in Fig. 321.

As usual the first thing to do is to locate points on the joint or curve of intersection, and when this is done the

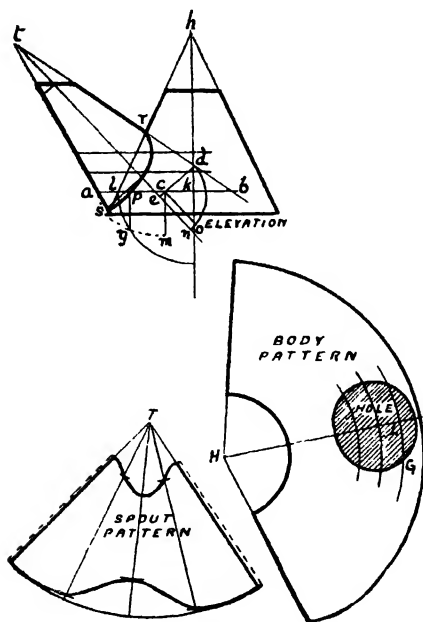


FIG. 321.

ordinary method of getting out a pattern for a part cone (Chapter XIV.) can be applied.

The obtaining of one point ( $p$ ) only is shown, as all the others will be found in exactly the same manner. The

centre line  $t n$  of the spout cone is first drawn and  $r s$  divided into four equal parts, and lines drawn across as shown by  $a b$  and the others. The middle point,  $c$ , of  $a b$  is next determined and the line  $e d$  drawn through it square to  $t n$ . A quarter-circle is constructed on  $e d$ , and  $c o$  drawn parallel to  $e n$ . The line  $c m$  is next drawn perpendicular to  $a b$  and cut off equal to  $c o$ . The quarter ellipse,  $a g m$ , is now constructed by the trammel method (Chapter XXI.), and the point  $g$  determined by describing the quarter-circle on  $l k$  to intersect the ellipse. A perpendicular is now run up from  $g$  to cut  $a b$  in  $p$ ; which will be a point on the elevation of joint curve. In the same way points can be found on the other two lines.

There is no need to describe the marking out of the spout pattern, as this is done in former chapters, but the method of obtaining the shape of the hole on the body pattern is worth considering. Mark off  $H L$  equal to  $h l$ , and draw around the arc, cutting off  $L G$  equal in length to the arc  $l g$  on the elevation. In the same way other points can be found which, when joined up, will give the shape of the hole.

### Oblique Circular Hood Fitting on Round Pipe.

The intersection of an oblique cone with a cylinder, as shown in Fig. 322, presents a way by which a circular-mouthed hood can be run into a vertical pipe.

The determination of the joint line and the method of getting the lengths of the pattern lines will be shown for one point only. The plan and elevation of the oblique cone and the setting out of the full pattern are just the same as shown in Chapter XVIII. A line is first run up from  $b$  to  $b'$ , joined to  $t'$  and cut through at the point  $a'$  by a line run up from  $a$ . Now using  $t$  as centre draw the arcs  $a c$  and  $b B$ ; joining  $B$  to  $t'$  and drawing a line up from  $c$  to cut  $B t'$  in  $A$  (or  $A$  can be found by drawing a line across from  $a'$

to cut B  $t'$ ). The line T A on the pattern is then marked off equal to  $t' A$  in the elevation. In the same way the other points for the pattern can be obtained.

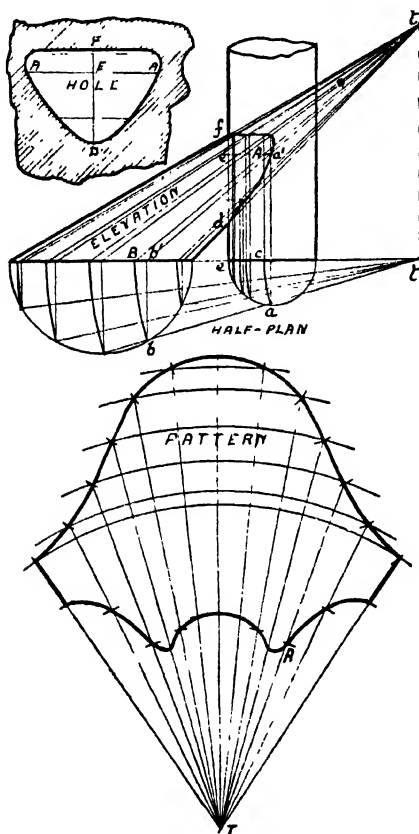


FIG. 322.

The shape of hole for the cylindrical pipe can be drawn by making D E and D F respectively equal to  $d e$  and  $d f$ ,

and the distance  $E A$  equal in length to the arc  $e a$ . In a similar manner the other widths of the hole can be determined.

### Gusset Plate for Round Pipe Elbow.

The exact shape of the pattern for a gusset may be found as set out in Fig. 323.

A quarter-circle is described, divided into three equal parts, and lines run up to meet the joint line of gusset in  $O'$ ,  $1'$ ,  $2'$ , and  $3'$ . The middle line  $O'3'$  is next drawn, and lines run across and cut off equal in length to the quarter-circle lines; that is,  $O'0'' = a o$ ,  $1'1'' = b 1$ , and  $2'2'' = c 2$ . From the dotted curve thus obtained the girth line of

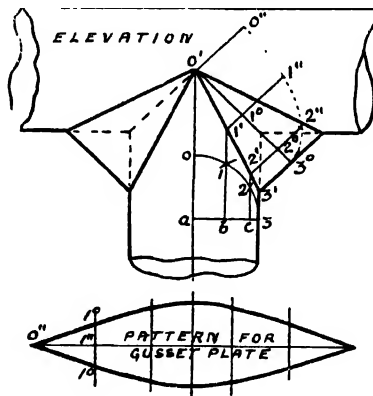


FIG 323.

pattern is measured, set down, and construction lines drawn across; these latter being cut off equal in length to the lines on gusset elevation. Thus, to give one example,  $O''1''$  on the pattern will equal  $O'1'$  on the elevation, whilst  $1'1''$  will be the same length as  $1'1'$ .

### Round Pipe Elbow with Twisted Arms.

A peculiar case of an elbow is that shown in Fig. 324, where one arm is twisted so that the elbow would not lie flat on a plane surface, or geometrically, when the centre lines of the arms are not in the same plane.

This is usually made up with the middle piece telescopic, so that the elbow can be twisted into its proper position. In any case the correct angles that the arms make with the

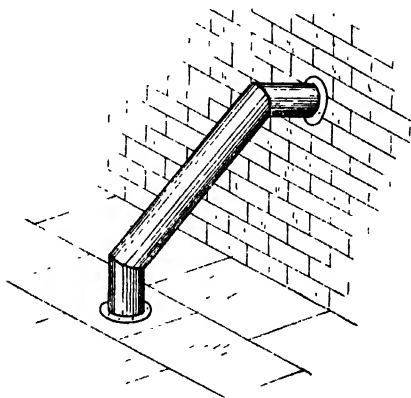


FIG. 324.

middle pipe must be determined, and it will perhaps be an advantage, also, to show how the pattern for the middle part may be set out in one piece.

In Fig. 325 a plan ( $a\ b$ ) and elevation ( $a'\ b'$ ) of the centre line of the middle pipe is shown. The angle for the bottom elbow can be found by drawing  $b\ B$  square to  $a\ b$  and making it equal to  $c'\ b'$ . If a line then be drawn through  $a$  perpendicular to  $a\ b$  the bottom angle will be determined as indicated. The top angle can be set out by making  $a\ B'$

equal to  $a B$ , and drawing a line through  $B'$  square to  $B' b$ . Having found the angles the patterns can be struck out as shown in Chapter II.

To make the pattern for the middle pipe in one piece it will be necessary to find the true length of one line on the

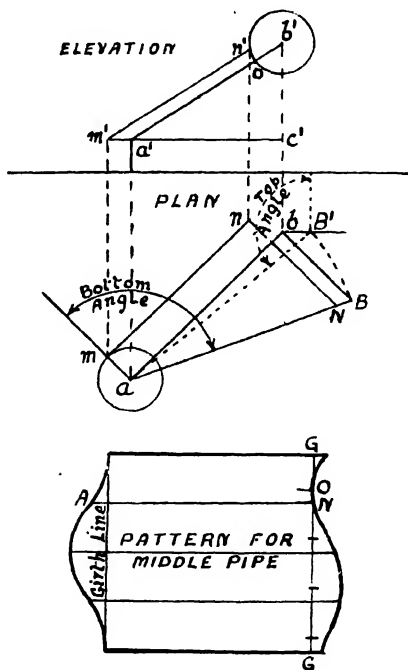


FIG. 325.

pipe and use this to set out the length of the pattern. Draw  $m n$  parallel to  $a b$ , and project down from  $n'$  to determine the point  $n$ . Now draw  $n N$  perpendicular to  $n m$ , and

so fixing the point N on *a* B. The length *a* N will be the true length of the side line of the pipe. Having set out the pattern cut for the bottom elbow (shown passing through A) the girth line should be divided into four equal parts, and lines run along as shown. The side line A N is made equal to *a* N from the plan. Next draw the line G G to pass through N and mark the distance N O equal to the length of the arc *n' o* in the elevation. The point O will be the throat part of the top elbow, hence the curve must be drawn as shown passing through the point N.

The patterns for the arms and the construction for the curves are not shown, as these will come out as explained in the early chapters.

## CHAPTER XXXV.

## SHEET METAL JOINTS.

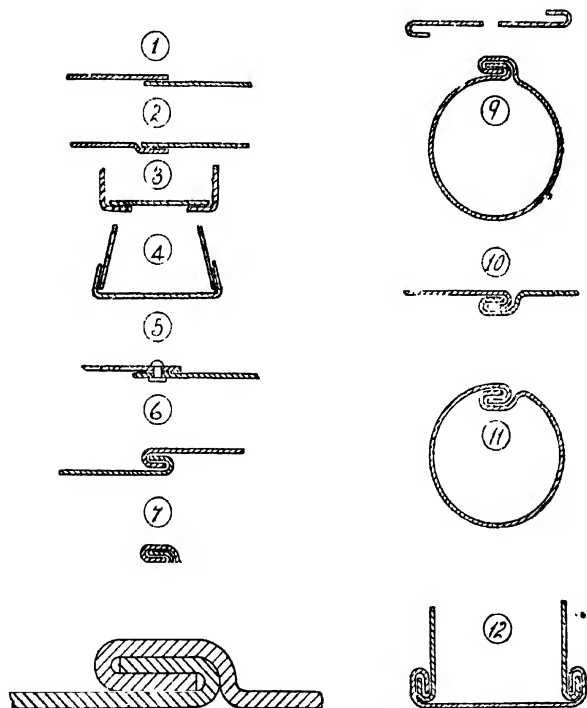
THERE are really only five ways in which the edges of sheet and plate metals can be fastened together—viz., by soldered, brazed, welded, grooved, and riveted joints. But whilst we are limited to the use of one or other of these forms of jointing, there are numerous modifications of them in practice.

The sketches of joints shown are enlarged somewhat, to better exhibit the layers of metal. (1) shows the ordinary lap-joint, as used in soldering together the edges of tinplate, zinc, or galvanised iron, the width of lap running from about  $\frac{1}{8}$  in. in thin tinplate up to  $\frac{1}{4}$  in. in galvanised iron.

To make a soldered joint is not a very difficult matter; but there are a few things that want to be taken notice of if the job is to be carried out successfully. The fluxes (anything that is used to assist the flow of metals) used are various; but those commonly in use are "killed spirits," and ready-prepared soldering fluids. "Killed spirits," or "spirits of salts," as it called, takes a good deal of beating for all-round work, as by its use almost any metal can be soldered, with the exception, perhaps, of aluminium. It is prepared by dissolving as much scrap zinc as possible in hydrochloric acid, the resulting liquid being known chemically as a solution of chloride of zinc. If the edges of the



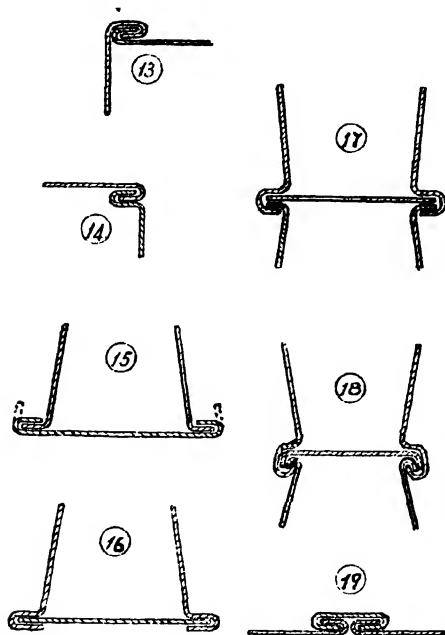
metal are clean, they can be lapped over without any preparation, and the spirits applied along the joint with a brush about  $\frac{1}{2}$  in. wide—a good brush can be made with a few bristles fixed into a strip of double-over tinplate. Before using the soldering-bit it should be seen that it is



properly tinned, and if not, get to dark-red heat, file the point about  $\frac{3}{4}$  in. along, dip in spirits, and then apply solder.

The mistake that the novice usually makes in soldering

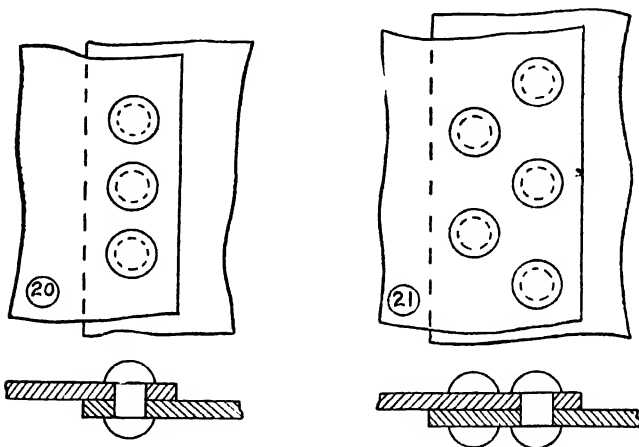
a joint is to stick the metal on like glue or putty, instead of holding the soldering-iron long enough against the joint for the solder to be properly melted and the joint to get sufficiently hot for the solder and sheet metal to firmly adhere together. Instead of using the extreme point of



the soldering-iron to run the solder on joint, an edge of the square point should be used to draw along the solder. In this way a greater quantity of heat will be transmitted to the joint, and thus a better and quicker job made.

The soldering-iron must be watched, so that it does not get red-hot, or else the tinning on its point will be burnt

off, or, what is worse, form a hard skin of bronze, which is somewhat difficult to file away. When the soldering-iron is drawn from the fire it can be cleaned by quickly dipping the point into the spirits, and also in this way one can judge as to its proper temperature. If when dipping the iron into the spirits much smoke is given off, or the liquid



spurts about, the iron is too hot; or, on the other hand, if small bubbles of spirit adhere to the soldering-iron it is not hot enough. An hour's practice should teach one the proper temperature at which to use the bit.

In soldering zinc or galvanised iron, if the soldering-bit is too hot the joint will be very rough on account of some of the zinc being melted from the surface of sheet and mixing in the solder. For tarnished zinc and galvanised iron, the spirits should not be quite "dead," that is, the scrap zinc should be withdrawn from the acid before the boiling action has quite ceased. It is, perhaps, a better plan,

though, to freshen up the "killed spirits" by adding a small quantity of neat acid.

In soldering copper, brass, and black iron, the edges of metal should be carefully cleaned before the lap is formed. One of the tests of a good soldered joint is that the solder shall have run right through the joint, and if this be done, and the joint properly cleaned with soda and water, there is little danger of corrosion from the use of chloride of zinc. The great drawback to the use of this flux is in the corroding action that takes place if any be left about the joint; perhaps the chief evil being when it is not properly driven out from between the laps with the running solder.

The next joint (2) is known as a countersunk or flush joint, and is used either for soldering or riveting where one face of the article is required to be level or flush. The crease also adds stiffness to the joint, and assists to keep the edges of the metal on the lap close down to the surface of the sheet or plate; (3) is a joint that is sometimes used for fixing a bottom in an article, either by soldering or riveting; the edge of the body of vessel is turned or flanged inside; (4) is an edge-over joint, generally used for readily attaching bottoms to articles by soldering and occasionally by riveting; (5) shows a riveted joint for sheet metal, the width of lap usually being about six to eight times the diameter of rivet. It is not the general custom to punch holes in the laps of thin metal before lapping over: the rivets are, as a rule, drawn through the two thicknesses of metal with a rivet-set or fetcher-up (Fig. 326), hammered down,

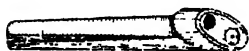


FIG. 326

and then snapped with the cup on upset. In making this kind of a joint the plan followed is to place the rivet on a stake or bar, bring the joint over it, and tap with the hammer, the position of the rivet being at once seen

by the slight mark or bright spot on the sheet; the article is then moved until it is found that the rivet is in its right position on the lap, it is then drawn through as before mentioned. Workmen—such as bucket makers and others of this class—become remarkably skilful in this blind kind of riveting.

The grooved joint (6) and (7) is perhaps the most universally used of all forms of jointing, and whoever invented it certainly conferred an enormous benefit on all classes of sheet metal workers. In making the joint, the edges of the metal are bent over, either with a mallet on a hatchet-stake or in a folding machine, and hooked together as in (6), and the seam placed on a bar or other tool, and grooved by hammering a groover (Fig. 327) whilst it is being moved along the seam. Care must be taken that the groover does not cut or mark the metal on either side of the groove. The joint is now flattened down with, in the case of thin metal, a mallet;

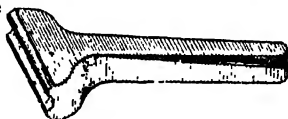
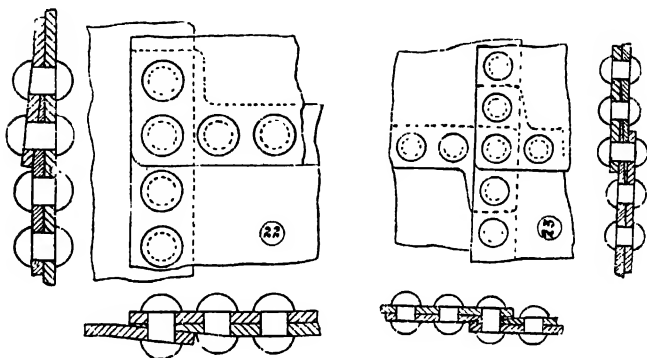


FIG 327.

and thick metal, a flat-faced hammer. An enlarged view of the finished seam is shown in (8). In a shop where much pipe or other grooved work is done, it is worth while having a grooving machine. The same kind of joint is shown in (9) as a longitudinal seam for a pipe. It should be observed that one edge of sheet is folded down and the other up.

In (10) and (11) a countersink or inside groove is shown. The use of this is to avoid having projections on the outer surface of an article. It is also used in jointing the zinc lining in coal-buckets, scoops, and similar things. For work of large diameter, where a groover can be used inside, this joint will be made in the ordinary manner; but for small work the edges are hooked together as in (6), the article slipped over a bar with a square edge, and the groove sunk with mallet or hammer.

(15) is known as a "paned down" joint, and is a ready means of edging a bottom on to an article. The body is stretched or flanged first, and the edge of bottom is turned up all round, as shown by dotted lines, the bottom slipped on to body and then paned down. In (12) the same joint is shown bent over again. This is known as a "knocked-

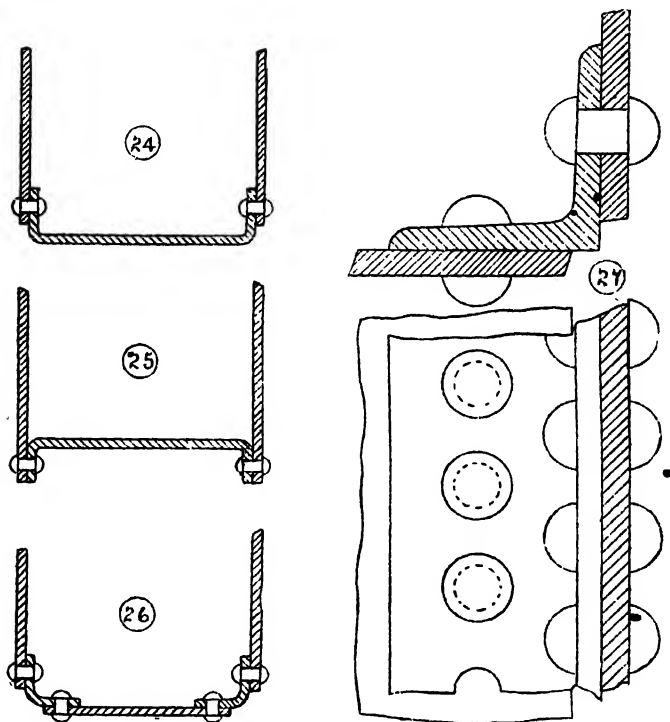


up" joint, and is commonly used for fastening bottoms on to all kinds of sheet metal vessels. If made properly, both this and the ordinary grooved seam should be water-tight without being soldered; but, of course, a better job is made if soldered as well. If an article is made up in black iron and then galvanised, no soldering should be needed. A similar joint to above is shown in (13), and in this form is used in seaming the corners of boxes or trunks. Another modification of this joint is shown in (29) and (30), and is used for joining together two pipes—end on, and also for attaching a neck or collar to the body of an article.

A cash-box joint is illustrated by (14); the object of this is to get the knock-up inside the box, and also to have the outside of corner flush.

Two further methods of jointing are explained by (16) and (31): they are sometimes used in fixing bottoms to articles.

The joint in (32) and the bottom seam in (33) are ways

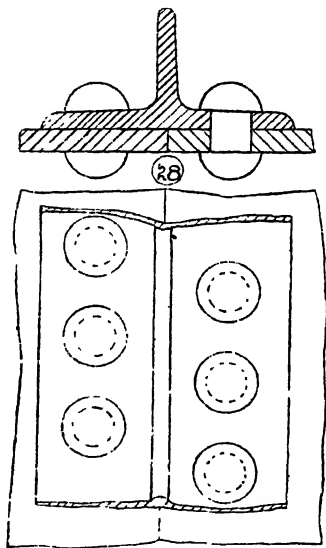


that are employed to attach bottoms and tops on articles by the use of the spinning lathe or other machine. The method

of jointing in (33) can also be used with advantage in fixing the bottom and top on to a closed vessel such as a cylindrical hot-water tank or other similar vessel.

To fasten a bottom and foot in an article with one joint, as in the case of a coal-bucket, the plan of joining shown in (17) and (18) is followed. The latter joint being, of course (17), knocked up.

In (19) a sketch is given of what is known as a double-grooved joint. This is an excellent plan for firmly holding

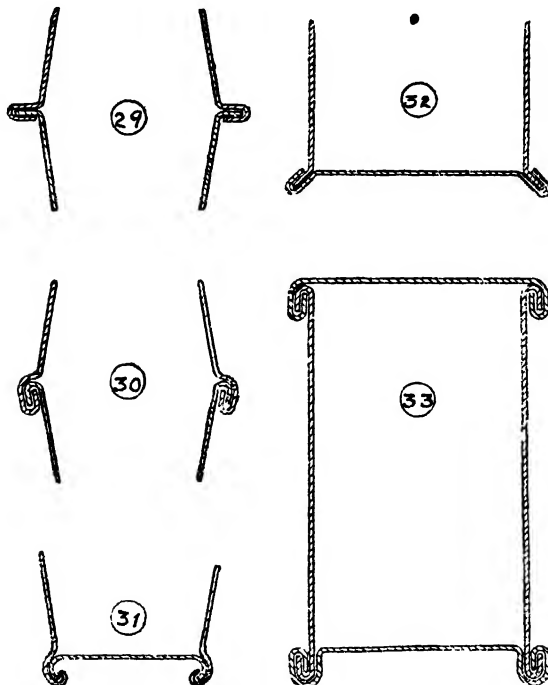


together the edges of round or straight-sided articles made out of heavy metal which is too strong to be grooved in the ordinary way. It will be seen that the strap is a separate strip of metal, which, after being bent, is slipped over the two edges, and then hammered down.



## Soldering and Brazing.

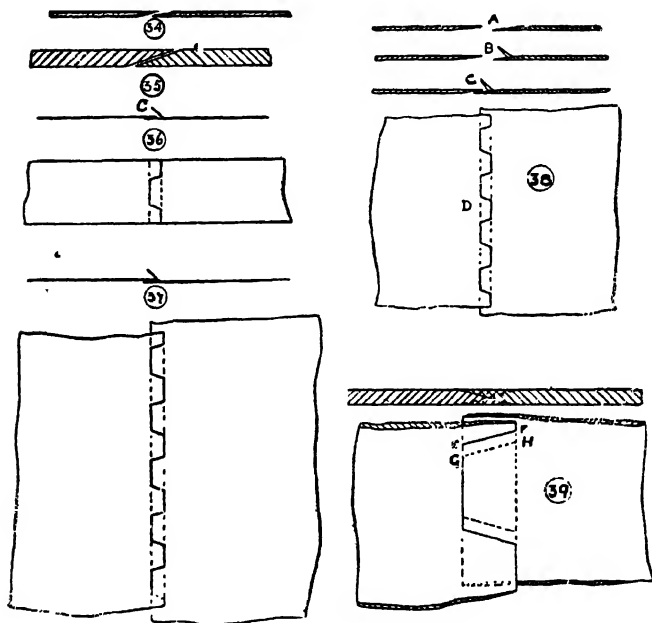
Every mechanic who is a worker in any kind of metals should at least be able to make a simple soldered or a brazed joint. To acquire a knowledge of the operations is not at



all difficult, a working acquaintance being readily obtained after a few hours' practice.

The operations of soldering and brazing are not analogous to those of gluing, gumming, or cementing, as it is not simply a question of inserting some adhesive substance in between the two surfaces of the joint, and thus sticking the

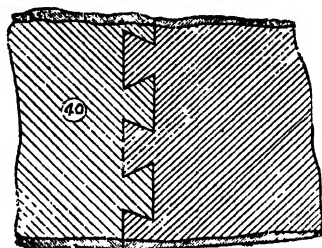
metals together. When two edges or surfaces of metal are soldered or brazed together, the solder or spelter actually alloys with the metal to be soldered for some small distance



beneath the surface; hence the solder or spelter penetrates into the pores of the metal, and thus obtains a firm grip. If a joint be cut through and the section examined under the microscope, no clear line of demarcation between the solder and the metal can be observed. For instance, if the metal soldered is copper, it will be noticed that the bottom layers are yellow, the solder having combined with the copper and formed a bronze. In a brazed joint the spelter will have alloyed with the copper and thus formed a brass.

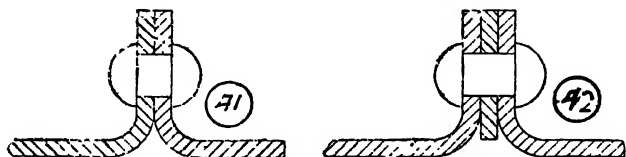
Considerations such as above will lead to the conclusion that for a joint to be properly made, the temperature of the melting solder or spelter and of the joint to be soldered is of some importance.

Before proceeding to describe the methods of making the above kind of joints, it will be as well to first consider the subject of solders and fluxes.



In making or choosing a solder the requirements of a good solder should be kept in mind. They are as follows:—

1. The melting-point must be below the melting-point of the metals to be soldered.
2. The solder must flow readily.
3. The solder must firmly unite with the metals to be soldered.
4. The solder must be strong.



Let us consider the above requisite properties of a good solder or spelter. In the first place, it would manifestly be

foolish to attempt to solder a metal with a solder whose melting temperature was higher than that of the metal to be soldered, as before the solder commenced to run the sheet itself would have a hole melted in it. So that, in soldering the softer metals, such as block tin and pewter, care must be taken to choose the proper solder.

For the solder to properly permeate every part of the joint it is, of course, necessary that it should become liquid or thin, so as to flow readily. To obtain this property all foreign substances must be kept out of the solder. Thus, to give an illustration, if a small quantity of zinc gets into a soft solder composed of lead and tin, it makes it become thick or pasty in use.

From what has been said at the commencement it will be readily understood that the solder must be of such a nature as to alloy with the metals to be soldered, or else it will be impossible to make a firm joint.

For iron, copper, or brass work that is to be subjected to pressure, it is essential that the joint shall be as strong as possible. Hence, in making joints for this kind of work a brazing spelter must be chosen that will give the best results.

- The following is a table of a few of the soft solders in ordinary use:—

		Lead.	Tin.	Melting-point.
Coarse plumber's solder	...	3	1	480° Fahr.
• Ordinary     "     "	...	2	1	440     "
Blowpipe     "     "	...	1	2	340     "
Fine tinman's     "	...	2	3	335     "
Ordinary     "     "	...	1	1	320     "
Pewterer's solder	... {	1	1	201     "
	Bismuth	2		

It is interesting to notice the change in the melting-points of the solders from that of the metals which form them.

Thus, lead melts at 620° Fahr., and tin at 440° Fahr., yet when these are alloyed together in equal proportions to form ordinary tinman's solder, the melting-point drops to 320° Fahr. This is one of the advantages that is derived from the alloying of metals.

It is generally the best plan to make one's own solder, as much of that which can be bought is unreliable. Besides which, without some guarantee that the solder contains the required proportions of lead and tin, there is no knowing whether or not there is more lead in the solder than has been bargained for. Tin being about ten times the price of lead, a small reduction in the quantity of tin makes a considerable difference in the value of the solder. A rough test of the quantity of tin in a solder is by listening to the characteristic "cry" of the tin when the solder is bent.

In making solders, the lead and tin are melted together, the metals properly mixed, and the scum or oxide skimmed off the surface. And before pouring into the mould, it is a good plan to dust a little resin on the surface of the solder, and let it burn away. In lieu of a cast-iron mould, a bar of small angle-iron can conveniently be used for running the sticks of solder.

It will be noticed that pewterer's solder melts some degrees below the boiling-point of water; but it does not of necessity follow that boiling-water will melt away the solder from the joint on a pewter vessel, as the solder, by virtue of alloying with the pewter, will, in this case, have its melting-point raised.

The following table gives the composition of the ordinary hard solders or spelters:—

			Copper.	Zinc.	Silver.
Iron work...	...	...	2	1	0
Copper and thin iron work	...	...	3	2	0
Brass work	...	...	1	1	0
Thin brass work	...	...	8	8	1

The term "spelter" should not be confused with the same name that is applied to ingot zinc, as a hard solder is essentially a brass, whilst, of course, ingot zinc is almost pure zinc, and is principally used in galvanising. It will be seen that the first spelter has the same composition as ordinary brass, and it might be here said that sheet brass is often used, instead of brazing spelter, as it is sometimes found to be more convenient to put along the joints. In bent joints, such as that in a kettle spout, a strip of brass can be cut that will lie along the whole length of the joint.

In practice there is really very little need to trouble about the composition of brazing solders, as they are usually sold in a graded form, numbers 1, 2, 3, etc., the coarse being used for iron and the finest for thin brass work. Silver solders, mostly composed of copper and silver, are used principally in jeweller's work, with which we are not here concerned.

The fluxes used in soft-soldering are "killed spirits," resin, resin and oil, tallow, and for pewter Gallipoli oil. Soldering fluids are sold ready made-up, and these are probably composed of crude chloride of zinc, with some salammoniac in solution. A lump of salammoniac is sometimes used for cleaning the point of the soldering-bit, and powdered salammoniac is used as a flux in various tinning operations.

Borax is almost generally used as the flux for brazing. There are, however, several advertised substitutes; but the principal ingredient in these is probably borax in some form or other.

It may be noticed in passing that the object of using a flux is to assist the solder to flow, and to keep the part of the joint which is being soldered from contact with the atmosphere. The air being kept from contact with the surface of the joint, no oxides can form, consequently the melted solder is free to unite with the heated metal. In

many cases, too, the flux has a cleaning action, removing any thin film of oxide that may have formed on the surface of the sheet previous to soldering.

### Brazing Joints.

Brazing joints are important, as they present to us the somewhat peculiar instance in which it is possible to make a joint as strong as the solid plate. In ordinary riveted joints it is never possible in workshop practice to make a joint as strong as the rest of the plate, the strength of the joints varying from about 55 per cent. in single-riveted joints up to about 80 per cent. in treble-riveted. In a properly made brazed joint, however, either in iron, copper, or brass, the joint will be found to be as strong as the rest of the plate. The present writer has made many experiments on the strengths of brazed joints, and has invariably found that when properly made the joint is as strong as the sheet or plate.

The sketches numbered (34) and (35) show sections of the ordinary wedge or scarf joints, which are used in thick or heavy work, such as steam-pipes. The edges of the plates are thinned down to form the scarf as shown. There is some difference of opinion as to the proper length of the scarf, but the writer has found in all his tests that if the length of the scarf be made equal to three times the thickness of the plate, it gives a joint which is stronger than the rest of the plate. Perhaps in the thinner metals that are brazed together with this form of joint, it will be found convenient to make the scarf a little longer than above. To ensure the spelter properly running into the joint, the surfaces of the metal should be carefully cleaned, and borax water allowed to run through between the metals before attempting to put the work on the fire. One can generally assure that if the metals are clean and carefully fluxed, the spelter will follow the flux. Another point to remember is

that the joint must not be too tightly clamped, or else the spelter will not be able to work its way into the joint. When the job is being brazed, if the spelter is not running properly through the joint, a good plan is to gently tap the plate, which will set up a slight vibration at the joint, and thus assist the spelter to percolate through the joint. At the same time, the melting spelter should be kept dusted with borax powder.

After brazing, the surplus spelter is removed, spent borax and oxide scaled off, and the joint hammered. Excessive hammering should be avoided, as the metal at the joint becomes hard and brittle, and at the best the joint is never as ductile as the rest of the plate. Where there is danger of the joint cracking under pressure it should always be annealed, so that the metal will be soft, and thus stretch somewhat before coming to the breaking point.

This kind of joint is also used in jointing or repairing band-saws. The saw is usually thinned down over a length of two teeth by filing or grinding. To hold the saw in position the writer has generally found it convenient to make a couple of plates, as shown in Fig. 328, fixed the band in between, and bolted together.

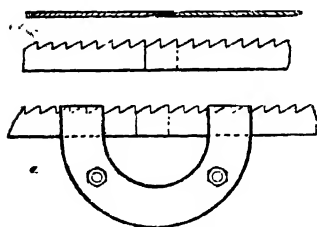


FIG. 328

To braze, the borax and spelter are put in between the joint, and the joint gripped with a heavy pair of blacksmith's tongs, previously made red-hot.

Sketch number (36) explains the way in which the two edges of a band or hoop can be brazed together by first cramping the edge of one end.

Number (37) illustrates the general method in use for making a brazed joint in thin sheet iron. The cramps are



first cut as shown on the right-hand piece, and every alternate cramp lifted, as seen in the section. The left-hand plate is then slipped in and the cramps hammered down. In ordinary sheet-iron work there is no need to clean the edges, as the fused borax sufficiently removes the scale on surface to allow the spelter to come into contact with the iron. After brazing, the joint is usually hammered to remove any inequalities of surface and to chip away the remaining borax and oxide of iron.

The method followed in making a brazing joint in copper or brass is shown in number (38). The edges are first thinned by hammering, as in A, and then properly cleaned. Cramps are nicked and lifted, as at B, and the edges brought together, as at C, and then hammered down, as at D. In copper work it is usual to cut the cramps by holding a strong knife on the slant, and drive it into the metal with a hammer. This plan of cutting ensures that when the cramps are hammered down there will be no thick edges at the side of the cramps, and that the joint can be made perfectly flush and the same thickness as the rest of the plate. An enlarged view and section of one cramp is shown in number (39). The line E F and the dotted line G H show how the plate is cut on the slant, so that the cramps may be thin on the sides as well as at the ends.

Joint number (40) shows a dovetailed method of jointing that is occasionally used in brazing together two plates of iron or steel where the surface is required perfectly flat. It is a difficult joint to make on account of the accurate work required in fitting, and when done, is not any better job than the ordinary scarfed joint.

In brazing a side seam on a circular vessel, the operator should be careful not to let the spelter run away from the joint. To avoid this, the brazing-mixture should be placed just along the joint. A plan often adopted is to bend the body of the article into some such shape as Fig. 329, and

fasten with a pair of dogs or clips. The sharp curve about the joint will ensure the spelter running only along the joint. After brazing, the article can, of course, be readily shaped to its proper form.

The joints in circular work are often held together by passing binding-wire around the article and twisting up tightly. To keep the joint from springing open in sheet-iron work, a good method is to bend or roll the sheet to a much smaller radius than required; pull out and let the joint spring together. And again, if the cramps are carefully knocked down, beginning at the points first, these should materially help to keep the joint from opening on the fire, and thus do away with the necessity of binding with wire.

The three sketches of Fig. 330 show the way in which a bottom can be fixed and brazed

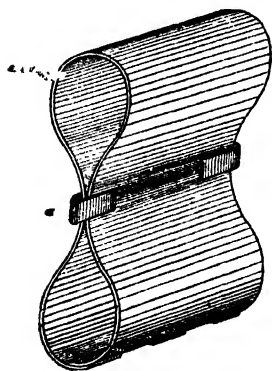


FIG 329.

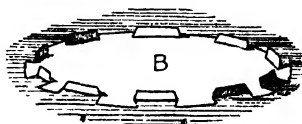
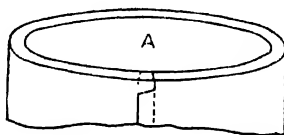
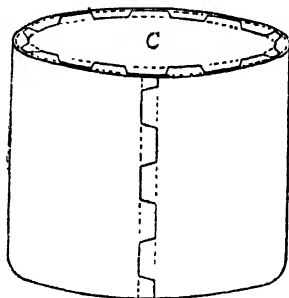


FIG. 330.

into a round article made of sheet iron. The bottom edge of body is turned or flanged in with a mallet, as shown in A. A circular bottom is cut out a shade less in diameter than the inside of vessel, and the cramps snipped and turned up as in sketch B. The bottom is now slipped into the body, and the cramps hammered down over the edge, as shown in C. In brazing, the article should be tilted on the fire so as to ensure the spelter being concentrated on the joint.

In all brazed joints it should be observed if the spelter has run through the joint and fastened the cramps on the outside, as this is the test of a good solid braze.

### Brazed Outlet or Tee-Pipe.

Figs. 331 and 332 show outside and sectional views of the way in which an outlet may be brazed on to a pipe. The

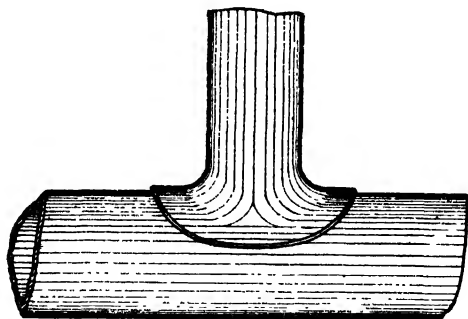


FIG. 331.

outlet is flanged to fit on the main pipe as shown, whilst the hole in the latter is made small to begin with and gradually worked out to the required size. After being thoroughly cleaned the two are wired together and carefully brazed.

### Pipe Flange Brazing.

In brazing on pipe flanges (see sketch of four-way piece in Chapter XXIX.) great care must be taken that both they and the pipe ends are properly cleaned. The flange should be slipped a little over the edge of the pipe, and the latter turned over on to the flanges to prevent the spelter from running through. Fireclay should be rubbed around the collar, and if the pipe is a brazed one, along the seam to

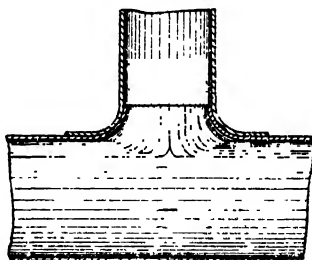


FIG 332.

protect from fire. To keep the heat on the joint a sheet-iron stopper should be placed in the pipe just above the flange, with fireclay rubbed around its edges. In brazing, great care must be taken to ensure the spelter running through the joint. While hot the brazed flange should not be treated too roughly, as the brass is very brittle in that state. When cold, the face of the flange should be cleaned up, and all superfluous spelter removed.

## CHAPTER XXXVI.

## RIVETED JOINTS.

THE making of a good sound riveted joint is one of the most important operations in plate metal work; hence in this chapter we intend to consider a few of the main points that should be taken into account in the designing of a properly constructed joint. To design a riveted joint to give the best possible results with any given material for some particular purpose is not by any means a simple matter, and in the more complicated cases is somewhat outside the scope of a plater or boiler maker's work. We shall therefore deal only with the common forms of joints.

In the first place, it should be remembered that in ordinary practice it is never possible to make a riveted joint equal in strength to the solid plate, the relative strength of joint to plate varying from 50 to 90 per cent., according as to whether it is single, double, or treble-riveted, lapped or butted, punched or drilled, or iron or steel plates and rivets.

To increase the strength of the joint, it has been proposed to thicken up that part of the plate which forms the joint. Whilst theoretically there is no doubt but what this plan would give a joint equal in strength to the rest of the plate, practically it would not act on account of the cost and difficulty of rolling plates with thickened edges, and the awkwardness in their manipulation. In some cases welding is resorted to; but even in this, the uncertainty of the joint being welded right through makes it doubtful if a

welded joint is, on the whole, any stronger than a riveted joint. For furnace plates there is not so much harm, as the joint here is in compression, whilst in the shell-plates the joints are, of course, in tension.

### • Diameter of Rivets.

With any given thickness of plate, the first thing to determine is the diameter of the rivet which is most suitable for the joint. And, in considering this, we shall see that there are several practical considerations which assist us in arriving at the best size. If the holes are to be punched in the plate we shall find that it is practically impossible to punch holes of less diameter than the thickness of the plate. Even with holes equal in diameter to the thickness of plate, it will be necessary to have a large clearance between the punch and die or else the punch will break, and this arrangement again will give a very much tapered hole. Therefore, in practice, it is not a good plan to punch holes of less diameter than  $1\frac{1}{4}$  times the thickness of the plate.

On the other hand, to form a good joint the rivet must ~~not~~ be of too great a diameter, as this will entail a broad lap; and the rivets being set at too great a pitch, consequently it will be difficult to get a perfectly tight joint; and even if properly caulked, changes of temperature would soon cause the joint to open and leak. The difficulty of small holes is, of course, overcome when the holes are drilled; but here again we are met with a practical difficulty, and that is if too small a rivet is chosen a much larger cost is incurred in drilling and riveting on account of the greater number of holes required in the joint. Taking all things into consideration, the common rule of making the diameter of rivet equal to one and a quarter times the square root of the thickness of plate is a good guide

to assist us at arriving at a suitable diameter. The rule is conveniently written in this form—

$$d = 1.25 \sqrt{t}$$

A very simple way of obtaining the required diameter (for those who cannot readily calculate) is shown in Fig. 333. A line is drawn, and along it a distance of 1.44 in. marked, and then on to this the thickness of plate is added. A semicircle is now described on the whole line, and a perpendicular run up as shown. The length of this line will give the required diameter of rivet. In Fig. 333 the construction is for  $\frac{3}{4}$  in. plate, and it will be seen that the rivet diameter comes out nearly  $1\frac{1}{8}$  in. The nearest ordinary size to the calculated or measured dimension will have to be chosen. Thus for a  $\frac{1}{2}$  in. plate—

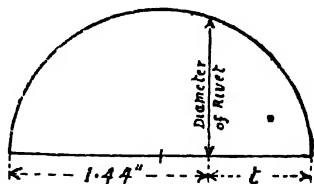


FIG. 333.

$$d = 1.2 \times \sqrt{.5} = .84 \text{ in.}$$

and the nearest stock size to this would be  $\frac{7}{8}$  in.

Generally, the diameter of rivets to suit particular thicknesses of plates will be:—

Plate thickness	...	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
Diameter of rivet	...	$\frac{9}{16}$	$\frac{3}{4}$	$\frac{7}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{4}$

Rivets for general work, such as girders, roofing, and ship plating, are usually a little less in diameter than in the above table.

### Pitch of Rivets.

The distance from centre to centre of the rivets can be calculated from the principle that the part of plate in be-

tween each pair of holes should be the same strength as one rivet. "It may be put in the form of a rule as follows: "The area of plate between a pair of holes multiplied by the tensile strength of the plate material, is equal to the cross sectional area of rivet multiplied by the shearing strength of the rivet material," or—

$$(p - d)t \times T = d^2 \times .7854 \times S.$$

Where—

$p$  = pitch of rivets.  
 $d$  = diameter of hole.  
 $t$  = thickness of plate.  
 $T$  = tensile strength of plate.  
 $S$  = shearing strength of rivet.

For iron  $T$  may be taken as 22 tons

"	"	$S$	"	"	"	19	"
"	steel	$T$	"	"	"	28	"
"	"	$S$	"	"	"	23	"

It should be noticed that  $d$  represents the diameter of the hole in plate, and this will for punched holes be about  $\frac{1}{8}$  in. larger than the diameter of rivet for, say,  $\frac{3}{8}$  in. rivets, varying up to  $\frac{1}{4}$  in. for 1 in. rivets.

For the sake of clearness it will, perhaps, be as well to work out an example in the use of the above formula. Suppose we require to find the pitch of rivets for a single-riveted lap-joint, steel plates and rivets. If the plates are  $\frac{1}{2}$  in. thick the diameter of rivet should be  $\frac{7}{8}$  in. Adding  $\frac{1}{8}$  in. on to this to allow for clearance, it gives a finished rivet diameter of .9 in. So that we have—

$$(p - .9) \times .5 \times 28 = .9^2 \times .7854 \times 23,$$

from which we obtain—

$$p = 2 \text{ in.}$$



The above calculation is based upon the assumption that the holes have been drilled, and in cases where the plates are drilled in position, it will be an advantage to take the clearance as slightly less than that allowed.

For punched work it is important to remember that the operation of punching damages the plate for some small distance all around the walls of the holes. Investigation seems to show that the plate is fractured for a distance of about  $\frac{1}{8}$  in. from the edge of hole. So that, in using the above rules for punched plates,  $\frac{1}{8}$  in. must be deducted from the space between the holes before proceeding to use the equation to obtain the pitch. It thus becomes—

$$(p - d - \frac{1}{8})t \times T = d^2 \times .7854 \times S.$$

Suppose we want to find the pitch of rivets for a single-riveted lap-joint formed of iron plates and rivets. Plates  $\frac{5}{8}$  in. thick, punched holes, and rivets 1 in. diameter. Adding  $\frac{1}{8}$  in. on to rivet diameter for clearance, we have—

$$(p - 1\frac{1}{8} - \frac{1}{8}) \times \frac{5}{8} \times 22 = (1\frac{1}{8})^2 \times .7854 \times 19$$

or— $(p - 1.06 - .2) \times .625 \times 22 = (1.06)^2 \times .7854 \times 19$

from which —  $p = 2.5$  in.

For boiler work little attention need be given to the construction of joints with punched holes, as all good work is now drilled in position, one or two small tacking holes only being first put in the plates in the flat, the remainder being drilled after the plates are rolled and bolted together. Indeed, with a spacing arrangement attached to a drilling machine, there is no need to mark off the holes with the exception of those needed for tacking. It might be here remarked that after drilling, the plates are separated, and the burr or aris cleaned off, so that the plate surfaces may come into dead contact in riveting.

There is no need to calculate the pitch for every thickness

of plate, as the space in between a pair of holes is the same in each case. Thus, for a single-riveted lap-joint formed of iron plates and rivets, with punched holes, the

$$\text{pitch} = 1\frac{1}{2} \text{ in.} + \text{diameter of rivet,}$$

and a similar joint of steel will have a

$$\text{pitch} = 1\frac{1}{8} \text{ in.} + \text{diameter of rivet.}$$

The space between the holes in a double and treble-riveted lap-joint will work out to about twice and three times, respectively, that of a single joint as above.

In general work, which has not to be subjected to much pressure, the pitch of rivets is usually taken greater than that shown in the above calculations.

### Width of Lap.

The distance of the centre of rivet from the edge of plate is generally taken to equal one and a half times the diameter of the rivet, so that a single-riveted lap-joint would have an overlap of three times the diameter of rivet, and a double lap five times the diameter, and so on.

### Caulking.

Where caulking is to be done for work which is to be subjected to pressure, it is important that the lap should not be greater than that named above, as the plates may spring in caulking or in use.

To caulk properly, the plate edge should be planed slightly on the bevel, as shown in joint No. 27. A too thin caulking tool should not be used, as this has a tendency to drive the metal under the edge, and thus spring the plate.

In arranging the position of joints on any kind of vessel, care should be taken that they are so placed that the riveting and caulking can be conveniently done.

### Shapes of Rivets.

The heads and tails of rivets are of various forms, several of which are shown in Fig. 334. (a) shows a cup or snap-head and tail, the dotted lines also showing a nobbled head; (b) and (c) have pan or cheese tails, and (d) has a combined countersunk and pan tail, with a nobbled head; (b) and (c) show countersunk heads.

The required length of rivet to form any given shape of head can be calculated; but in practice, on account of the clearance varying and also the cup of the snaps not always being of the same size, it is the best plan to obtain the correct length by trial.

### Riveting.

The bulk of riveting is now done either by hydraulic or pneumatic power; but where the work is done by hand, it should be observed that the rivet is made red-hot the whole length, so that in being hammered down it may swell and completely fill the hole. The difficulty of making rivets entirely fill the hole is one of the disadvantages that hand-riveting has as compared with machine-riveting.

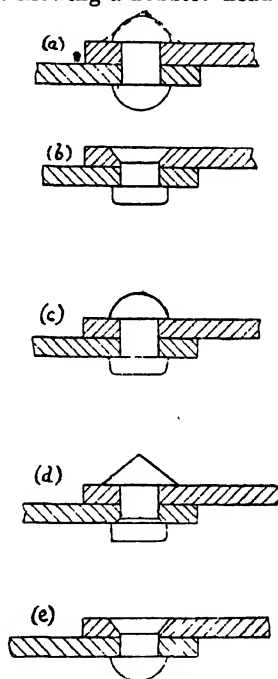


FIG. 334.

### Forms of Joints.

There are a multitude of different forms and combina-

tions of riveted joints. A few kinds only, however, will be shown—just sufficient to explain the arrangement of the plates. No. (20) shows the ordinary single-riveted lap, and (21) the double-riveted lap with zigzag riveting; (22) explains how three plates can be joined by smithing or thinning the edge of the middle one, and (23) shows a similar arrangement for joining four plates by thinning the corners of the two middle plates. Sections across both joints in each of the last two figures are shown, and by reference to these the formation of the joints should readily be understood.

The method of fastening flanged ends in cylindrical and other shaped articles is shown in (24) and (25). And (26) shows how corner or bilge plates may be fixed in, these again being sometimes riveted on the outside instead of the inside, as shown. (27) is a method adopted when two plates need fixing square to each other, the plates being joined by an angle-iron. A form of butt-joint is exhibited in (28), the strap or stiffener being of tee-iron. Sometimes the rivets, instead of being zigzag, are placed opposite each other to form what is known as chain-riveting. Joint (42) explains the method adopted for joining the ends of tubes, a stiffening ring of flat-iron being placed in between the flanges, and (41) shows the same without the ring.

### Strength of Joints.

The relative strength of joint to solid plate expressed in the form of a percentage will be equal to—

$$\frac{\text{pitch} - \text{diameter of hole}}{\text{pitch}} \times 100.$$

And using the example for  $\frac{1}{2}$  in. steel plates, already calculated, the strength of the joint will be—

$$\frac{2 - .9}{2} \times 100 = 55 \text{ per cent.}$$

The strengths of all kinds of joints can be multiplied out in a similar manner. Generally, drilled joints, on calculation, show up about 5 per cent. stronger than punched plates; but, practically, this percentage does not represent the difference in value between the joints, as with drilling there is no need for drifting holes, and consequently no local stresses are set up in the plates.

Butt-joints, with double straps, are the strongest form of joint, the strength of a treble-riveted joint of this description being about 90 per cent. of the solid plate. For longitudinal seams in a boiler, this class of joint also has the advantage of the plates pulling directly on the rivets and not obliquely as with a lap-joint. On account of the uncertainty of the stresses that are set up in a lap-joint, it is questionable whether it ought ever to be used in the longitudinal seams of a boiler.

### Bursting Strength of Cylindrical Shell or Pipe.

The bursting pressure of a solid shell or pipe can be determined from the following rule: "Multiply together the thickness of the metal and its strength in lbs., and divide by the shell radius in inches."

Thus, suppose a welded cylindrical boiler shell is 7 ft. diameter and  $\frac{3}{8}$  in. thick steel plate. Assuming that the strength of the metal is 28 tons per square inch, we have—

$$\text{Bursting pressure} = \frac{\frac{3}{8} \times 28 \times 2240}{42} = 560 \text{ lb.}$$

If the shell is riveted the above would have to be multiplied by the percentage strength of the joint to obtain its correct bursting pressure.

The strengths of steel or copper steam pipes can be found in the same way.

The above calculations will also serve to get out the re-

quired thickness of metal for a shell of given diameter to stand a given pressure.

As a somewhat curious fact it is worth noting that a spherical vessel of same thickness and material will stand just twice the pressure of a cylindrical vessel of the same diameter.

### Length of Angle, Tee-Bars, etc., for Rings.

The method of finding the lengths of flat-bars, etc., explained in Chapter XXXII., can also be applied to bars of irregular section. The important point is to find the position of the neutral axis. This will always pass through the centre of gravity of the section. The centres of gravity (see Chapter XXVIII.) can be found either geometrically,

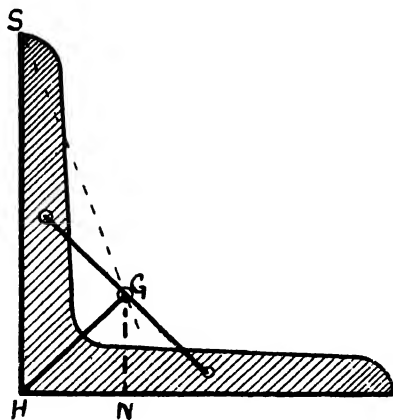


FIG. 335.

or better still for practical purposes, by the method of suspension. A section of the bar should be cut out of cardboard or sheet metal and suspended from a point (such as S in Fig. 335) and a vertical line drawn down. It should

then be hung from another point (such as H) and another vertical line drawn. Where these lines intersect will give the centre of gravity of the section. In Fig. 335 this is marked by the letter G, and when the bar is being bent, as shown in Fig. 336, either to form a ring with an outside or inside flange the neutral line will pass through the point N. To get the required length of the bar in the straight, the ring will be set out and the neutral circle drawn, and its

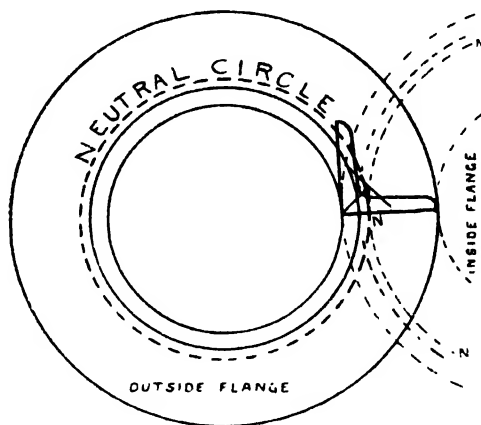


FIG 336.

length measured or calculated. For an inside flange part of the neutral circle is shown as N N N.

For the above to be true it should be remembered that uniformity of heating and bending is demanded.

In punching angles it might be here mentioned that it is usual for the centre line of the holes to run down the middle of the inside of angle-iron.

### To Calculate the Increased Length of a Bar when it is made Red-hot.

Problems on the expansion and contraction of metal bars are important, hence we give one example below.

Suppose a bar of iron is 10 ft. long and its temperature (that of the atmosphere), say, 30° C. It is placed in a furnace and got red-hot. How much will it lengthen?

A red heat is generally reckoned to be about 1,000° C. So that the increase in temperature would be 970°.

Now turning to the table of multipliers for linear expansion on page 451 we get that for iron, and our calculation works out as follows:—

$$\text{Increase in length} = 10 \times 12 \times 970 \times .000013 = 1.5 \text{ in.}$$

So that the increase in length comes to about 1½ in.

Calculations like above come in useful in making allowance when rings, bands, etc., have to be shrunk on.

### Planishing or Flattening.

To the uninitiated the levelling of plates or sheets presents one of the most awkward jobs it is possible to have. ~~But~~ with the exercise of thought and some practice the difficulties soon disappear. Before commencing to hammer a plate the position of the buckle or looseness should be carefully noted, and the blows placed accordingly. There are only two ways in which a plate may be buckled. It may either be sagged in the middle, as shown on plate "A" in Fig. 337, or it may be tight in the centre and slack along the edges, as shown by plate "B." On one plate there may be a combination of these two ways of buckling; one half may be slack in the middle and the other half slack on the edges.

The cause of buckling is due to unequal contraction of the sheet or plate in cooling, so that one part becomes longer



or shorter than the other. To bring the plate level, all strain must be removed, so that no one part of the surface shall be pulling against another. To do this all the short or tightened parts of the plate will require hammering. Thus in plate "A," where the buckle is in the centre, the hammer blows will need to be thickest at the outside of the plate, running away to nothing at the middle. In plate "B," where the edges are buckled or loose, the process will have to be reversed; the blows being placed about the middle and gradually dying away towards the edges.

The strength of the blows will, of course, depend upon the

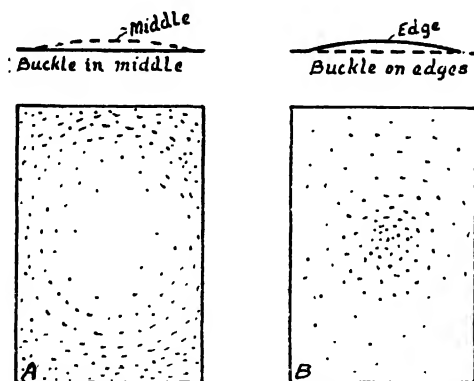


FIG. 337.

thickness of the plate. The inexperienced should always err on the side of light blows, as one heavy blow inadvertently given may require a hundred more to remove its ill-effects.

When particular work is required a flatter should be used to avoid the blows coming directly on to the surface of the plate. When the hammer alone is used great care must be taken so that its face edge shall not cut into the plate.

To obviate this, hammer faces for planishing purposes usually have a slightly outward curve.

Straightening rolls and other machines are now used for flattening plates and sheets, but where these are not available it is a good plan to run the sheet through the ordinary bending rolls a few times, reversing the sheet at each operation, as this tends to run the small buckles altogether and generally assists in determining how the sheet shall be hammered.

## CHAPTER XXXVII

## SURFACE TREATMENT OF SHEET METALS.

ALL metals more or less oxidise or corrode when exposed to a damp atmosphere or corroding fumes. And if the oxide so formed is dissolvable in water or other liquid, or readily detaches itself from the metal, as in the case of iron, then rapid deterioration takes place. Although iron has many distinct advantages over other metals in the way of strength, working properties, and cheapness, yet it is the worst of the ordinary metals in offering resistance to the action of air and moisture when exposed to the atmosphere without some protective coating. Copper, lead, and zinc are all quickly acted upon by damp air, or if the atmosphere contains sulphur, carbonic acid, or other fumes, the metals very soon tarnish. The thin film of oxide or scale so formed, however, in the case of these metals holds tenaciously to the metal, and, consequently, acts in a very effective manner as a protecting skin for the metal underneath. Aluminium, it has been said, is not affected by the atmosphere, but this is not true. Probably what happens is the instant formation of a *transparent* film of oxide. Again, sheet aluminium will not stand continued exposure in a damp atmosphere, as a heavy oxide forms on its surface, and if the sheet be thin the metal becomes very brittle.

To protect the surfaces of metals from corroding influences, many methods are in vogue, such as galvanising, tinning, electro-plating, dipping, lacquering, enamelling, japanning, painting, oxidising, and, for special purposes, metals may be coloured by bronzing, steeling, gilding, etc.

### Galvanising.

As galvanising is the commonest process adopted for applying a protective coating to sheet-iron work we shall explain the method followed with some fulness. Essentially the process consists in applying a thin film of zinc to the surface of the iron. We will first explain the plan followed for sheets and work on a large scale, and then give some hints of how best to deal with small articles. Before sheets can be galvanised all scale must be removed from their surface, and this is usually done in a pickling solution composed of equal parts of hydrochloric acid (or muriatic acid, as it is often called) and water. Lead-lined tanks are sometimes used for holding the acid; but the better plan is to have stone tanks, jointed with rubber packing, and held together with tie-rods. During the time the sheets are in the pickle they should be moved continuously, so that all parts of the surfaces may be equally exposed to the action of the acid. The length of time for pickling will depend upon the temperature and strength of the acid and on the condition of the sheet surfaces. If the acid is fresh and the sheets have been close-annealed (that is, out of contact with the furnace gases), then the pickling may be done in about fifteen minutes; but if the acid is partly spent, or the sheets covered with heavy scale (as the result of open-annealing), thirty to forty-five minutes will be required. Heating the acid (done in the early days of galvanising by blowing steam into the tanks) will increase the speed of working, but the character of sheet-surface produced will not be so good as when pickled by the cooler acid. Any increase of temperature over and above that of the atmosphere required for the effective working of the pickle is soon obtained by the heat generated through the chemical action. If the pickling solution is too hot the action upon the sheets is not uniform, and the surfaces will be somewhat

rougher. Occasionally a sheet will be found that contains a hard patch of scale or a scab, and this will have to be removed by a scraper or pick before attempting to pass through the galvanising bath. Sometimes a blister (a piece of double sheet which has not been properly welded in the manufacture) is found on a sheet, and great care should be taken to cut this away, as it will act as a receptacle for acid, which, when carried into the molten spelter, may cause a serious explosion. To obtain a good-looking surface after galvanising, the operator should be careful not to over-pickle, as this will cause the sheet to look "dead" and "dry." When properly cleaned the sheets are plunged into a water-tank for washing, and are then ready for the galvanising bath.

The quantity of acid used varies from  $1\frac{1}{2}$  to 4 carboys per ton of sheets, depending upon whether the sheets are close or open-annealed, or heavy or light. For economical working, the partly-spent acid from the large tank, when it becomes too slow for sheets, should be used as far as possible for small work, for which the time of pickling is not so important.

Where a large amount of work is done it is usual to test the acid with a Twaddell's hydrometer, the degree of reading, according to the density of the acid, varying from  $24^{\circ}$  to  $30^{\circ}$ . Without the acid is fairly pure the reading given on the hydrometer is not an exact indication of the strength of the acid from the galvaniser's point of view. A better and more effective test is to compare the relative amounts of zinc dissolved by equal quantities of acid taken from the different sample carboys. Thus, to give the result of one experiment: A certain quantity of  $24^{\circ}$  acid dissolves 5 oz. of zinc, whilst the same quantity of  $30^{\circ}$  acid dissolves 6 oz. of zinc. Their relative values, therefore, to the galvaniser are as 5 is to 6. In this way, by taking cost into account, it can be seen which is the most economical to use.

The amount of waste in pickling runs out to about 4 lb.

per 100 square ft. of open-annealed sheet iron to  $2\frac{3}{4}$  lb. per 100 square ft. of close-annealed sheet. This gives, as near as possible, 33 lb. to the ton of 16 gauge and 82 lb. to the ton of 24 gauge of the former, galvanised, and 57 lb. to the ton of the latter.

Before proceeding to explain how sheets are passed through the galvanising bath, it is as well to call attention here to the fact that the quality of the galvanised sheet surface will very largely depend upon the kind of surface that is put upon the black sheet. If the iron is of an inferior quality with a coarse surface, or is over-pickled, no amount of care in galvanising will produce a good surface. This, indeed, is true of all surface treatment, whether tinning, painting, lacquering, or whatever it may be.

A sectional elevation of a galvanising bath, with the rolls in position, is shown in Fig. 338. A layer of flux, about 6 in. thick, of crude salammoniac (or muriate of ammonia, as it is called) is allowed to boil up in the flux-box, a bit of tallow being thrown in occasionally. The sheets are taken one by one and passed into the pot through the flux-box, down through the feeding-rolls, and up out between the surface, or leaving-rolls, and taken away, either by hand or travelling chains, boshed in a tank of warm water, and dried by passing through a drying stove.

To ensure a clean galvanised sheet the surface-rolls must be kept clear of all waste flux and scum, and the flux in the flux-box must not be allowed to get too dirty, or else some of it will be carried through to the leaving-rolls and mark the sheets.

Up to within a few years back all sheets were either drawn through the clear or through sand, the feeding-rolls alone being used, and these, of course, simply to carry the sheet through the molten metal. One object of the surface-rolls is to give a more uniform coating of zinc and impart a little better surface to the sheet. The primary object, however,

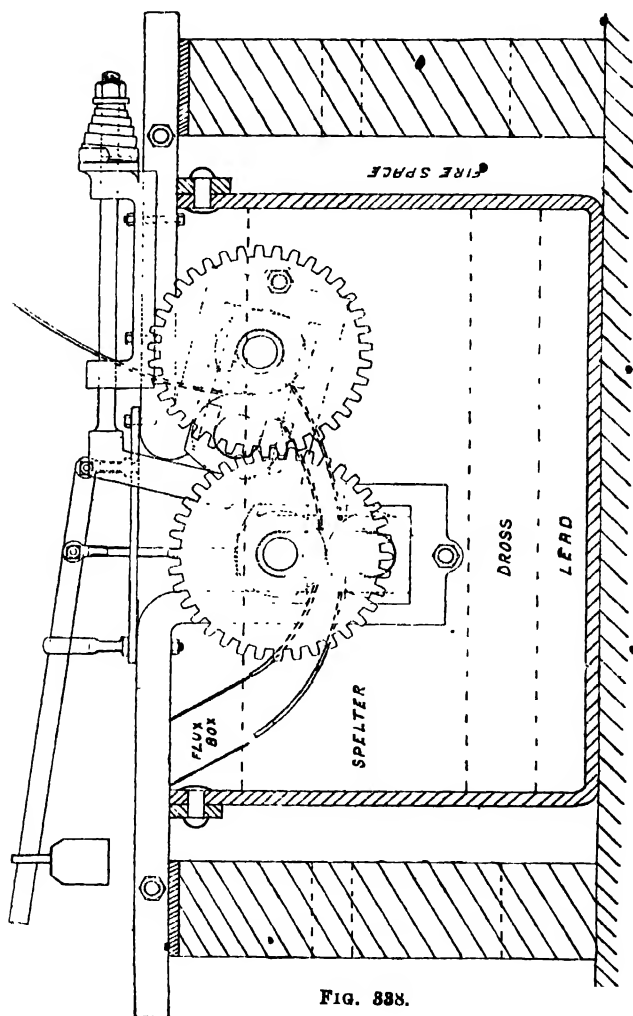


FIG. 838.

in the use of leaving-rolls is to squeeze as much zinc off the sheet as possible, and thus reduce the cost of manufacture. The result is that galvanised sheets of the present day are altogether inferior to what they were under the old system of manufacture. The following table, which has been compiled from experiments carried out by the writer, will give some indication of the altogether thinner coating of zinc which is now put upon sheets to that which was formerly the case:—

Kind of Sheets.	Spelter used per Ton of Galvanised Sheets.			
	Single Rolls.		Double Rolls.	
28 gauge ... ..	504lb.	...	310lb.	...
" 26 " ... ..	420	...	254	...
" 24 " ... ..	367	...	216	...
" 22 " ... ..	308	...	168	...
" 20 " ... ..	287	...	126	...
" 18 " ... ..	216	...	104	...
" 16 " ... ..	173	...	86	...

It will be noticed that, generally, the amount of spelter used in the modern process is only about half that which was placed upon the sheets under the old method. In consequence of this much thinner coating of zinc, the "life" of galvanising sheets is not by any means as long as it was formerly. In ordering large quantities of galvanised sheets, not only should the gauge of sheet or weight per square foot be specified, but also the thickness of zinc coating or weight of spelter per square foot to be added, if buyers desire to obtain sheets of lasting quality. By the old method it took from 15 lb. to 20 lb. of spelter to cover both sides of 100 square feet of sheet, whereas by the double-roll system only 9 lb. to 12 lb. of spelter are used in coating the same area.

Usually, when sheets are thicker than 16 gauge (that is,  $\frac{1}{4}$  in. thick) they are not run through the rolls, but are carefully dried and then plunged bodily into the molten spelter.



being drawn up on the opposite side of the pot through a thick layer of sand, or sand and ashes, kept moistened by water being sprinkled upon it.

The purer the iron the better the coat, might be taken as a rule in galvanising, and that is the reason why mild steel never takes as firm a coat as the best iron. Any impurities, such as carbon, silicon, etc., offer resistance to the formation of a tenacious surface alloy of iron and zinc. The harder the steel the more tendency there is for the spelter to peel off when the sheet is bent.

The remarkable liking which zinc has for iron, and which is its chief advantage in forming a good coating on galvanised work, is also at the same time its greatest drawback in the ready formation of dross. As the sheet passes through the pot small particles of iron are detached from its surface, which combine with the zinc, forming an iron-zinc alloy which gradually precipitates at the bottom of the pot, and which has to be periodically removed. Also the molten zinc slowly dissolves away the walls of the wrought iron or mild steel pot, forming additional dross, so that its renewal is required every six to twelve months or so. This is one of the constant worries and expenses of the galvaniser, and will never be altered until a different material for the pot, or another system of carrying out the process, is adopted. In the present writer's experience a pot that lasted longer than any other was constructed of wrought iron, which gave the following analysis:—

Carbon	...	...	...	...	trace
Silicon	...	...	...	...	·093 per cent.
Sulphur	...	...	...	...	trace
Phosphorus	...	...	...	...	·357 "
Manganese	...	...	...	...	·057 "
Iron	...	...	...	...	99·493 "
					<hr/> 100·000

For those who are interested in galvanising it may be useful to know the compositions of one or two samples of zinc spelter. The analyses of four specimens are given:—

	1	2	3	4
Zinc ... ..	99·900	98·80	98·526	98·34
Lead ... ..	—	1·036	1·002	1·535
Copper ... ..	trace	trace	·023	—
Cadmium ... ..	—	trace	—	·07
Tin ... ..	trace	—	·346	·015
Antimony ... ..	—	·087	·039	—
Iron ... ..	·084	·077	·014	·03
Arsenic ... ..	·010	—	·05	—
Sulphur ... ..	·006	—	—	01
	100·000	100·000	100·000	100·000

Sample No. 1, it will be seen, is an exceptionally pure specimen of virgin spelter. The other three are samples of metal of the kind ordinarily in use. Any iron in spelter is most objectionable, as it all helps to form dross in the pot. Most of the lead present in a spelter falls to the bottom of the pot and there accumulates.

Lead and zinc have very little affinity: hence the former metal usually separates out, and on account of its being heavier than either spelter or dross, settles at the bottom of the galvanising bath, as shown in Fig. 338. When a bath has been in use several months, as much as a 6 in. depth of lead will sometimes have accumulated. In case the pot is shallow, and it is necessary to remove the lead, this can be readily done by standing a tube (one about 12 in. diameter, and a little longer than the depth of molten metal, made of  $\frac{1}{8}$  in. plate will do) upright on the bottom of the bath, and lading out the spelter, when the molten lead will be forced up the tube, and can be laded out as required. The dross, on account of its greater density than spelter, and being lighter than lead, sinks through the former and

floats on the latter, as seen by the layers in Fig. 338. It is usually removed by a perforated spoon or ladle. Its composition is generally something like the following:—

Zinc	...	..	...	92.554	per cent.
Lead	...	..	...	.050	"
Copper	...	...	...	.103	"
Cadmium	...	...	...	trace	"
Tin	...	...	...	1.939	"
Antimony	...	...	...	.072	"
Iron	...	...	...	5.234	"
Arsenic	...	...	...	.012	"
Sulphur	...	...	...	.036	"
				<hr/> 100.000	

It will be observed that the pot is heated on the sides only ; any bottom heating having a tendency to make the dross rise and mix with the spelter, thus causing the surface of articles which are being galvanised to become rough. Great care should be taken not to let the spelter become red-hot, as undue heating spoils the surface of the object to be galvanised (giving it a "dry" appearance), and at the same time accelerates the formation of dross.

As much as possible of the top of the molten metal should be covered with sand, or sand and fine ashes, to prevent the atmosphere from coming into contact with the spelter, and thus forming zinc-oxide. Also it will reduce the loss of heat by radiation if the top of the unused part of the bath is covered with a plate of iron or other suitable material. Small articles can be readily galvanised by fixing up a small iron pot on an ordinary fire, or by gas-heating. In this case, when the spelter has been in use some time, it will be found to have become mixed with dross. To remove this, the molten metal should be allowed to settle, being kept in a liquid state by the application of a gentle side heat, the dross being then laded out.

The amount of salammoniac used per ton of work done will usually be about 9 lb. to 12 lb.

One disadvantage in the galvanising of objects having

riveted or lap joints, is that these parts hold traces of acid or flux, which soon sets up corrosion, and causes the parts to decay. It is difficult to avoid this, except by galvanising both before and after manufacture. It is an advantage to wash the joints down with weak soda-water, thoroughly dry, and then force into the joints a little boiled oil. Stains or black spots on sheets are caused in the same way as above. When the surface is brocky or porous, acid is absorbed which shows up a day or so after galvanising, by forcing out black spots of chloride of zinc.

In galvanising odd work, if there are any parts like screw-threads, etc., that do not require coating with zinc, these should be covered with white lead before the article is put into the galvanising bath.

For cooking purposes zinc-coated articles are useless, on account of the readiness with which zinc is dissolved by various organic acids; but for temporary uses, such as with buckets, baths, etc., the zinc-coating is all right.

### Tinning.

The process of tinning sheets follows very much the same lines as galvanising, the molten metal in this case being tin, and the flux generally a solution of chloride of zinc. The plates are run through several pairs of rolls, and ultimately up out through a "grease-pot" filled with palm oil.

Tinplate is of no use for outside purposes on account of the readiness with which it rusts. This is probably due to the fact that iron and tin have very little affinity to each other, causing the surface of the iron to be imperfectly coated. The microscopic points on the sheet left uncoated quickly rust when placed in a damp atmosphere, this being, no doubt, assisted by some electric action.

Terneplate is sheet iron or steel that has been coated with an alloy of tin and lead, the major portion of the alloy being composed of the latter metal.

Tin and copper have a very much greater liking for each other than tin and iron; therefore copper can be more readily and firmly tinned than iron. Its surface should be well cleaned, and then sprinkled with salammoniac, small pieces of tin placed on it, heated, and run over the surface, and finally wiped off with a wisp of tow. Any greasy parts on black iron or other metal that has to be tinned or galvanised, should first be either burned off or removed by a solution of soda. In tinning copper, if there are any parts that require to be left untinned, these should be first brushed over with whitening paste.

Tinned copper vessels make excellent cooking utensils where a quick heat is required, on account of the good conducting power for heat of copper, and also the cleanliness of a properly tinned copper vessel. Tin is not easily dissolved by vegetable or meat juices; but as copper quickly forms a poisonous verdigris, care should be taken to see that saucepans, etc., are kept properly tinned.

### Lacquering, Colouring, etc.

To obtain various artistic effects, metals are sometimes coloured by dipping into different chemical solutions or by the combined action of air and heat to form tinted oxides, or by the application of coloured lacquers. Lacquers are practically varnishes, and when properly applied, preserve the surface of the metal from being acted upon by an inside atmosphere for a considerable length of time. In japanning or enamelling, the work is stoved in a suitable oven after the application of the enamel, to give it the necessary hardness. Lacquering and other solutions for every possible purpose can now be so cheaply obtained that it is not worth while attempting to make them up. White or other enamelled utensils, for culinary use, have their surfaces treated with a vitreous matter, afterwards being baked in an oven or furnace.

**Protecting Plate Iron Work.**

For plate work, other than boilers, there is no more effectual initial coating than boiled oil. To be lasting, the plates should first be cleaned of all scale that is likely to become detached. When bars have to be riveted to plates, and where the atmosphere is likely to get between, the inner surfaces of both plates and bars should first be oiled over. One of the most fruitful causes of rapid deterioration in plate and constructional iron work, and which may have serious results, is the oxidation of parts of the structure that when put together are not get-at-able to be scud or painted. This should be guarded against as far as possible in the manner suggested above.

## CHAPTER XXXVIII.

## METALS AND THEIR PROPERTIES.

THERE are altogether in Nature between 50 and 60 different metals, but on account of the unfitness of many through difficulty of extraction from their ores, rarity, or rapid oxidation when exposed to the atmosphere, the numbers that can be used for general manufacturing purposes are only about a dozen.

The qualities possessed by metals which enable them to be used for so many purposes are:—

**Metallic Lustre**, or the property of reflecting rays of light.

**Tenacity**, or the strength with which the particles of which a metal is formed resist being pulled asunder.

**Malleability**. The property which many metals have of being hammered or rolled out into a large surface or thin sheet without fracture.

**Ductility** is the property which enables a metal to be drawn into a thin wire.

**Specific Gravity**, or relative weights of metals all compared to the weight of an equal volume of water.

**Conducting Power for Heat**. The property which metals possess in varying degree of transmitting heat along or through them.

**Conducting Power for Electricity**. The particular quality which metals have of becoming the medium for the passage of electricity

**Fusibility**. The property which metals possess of becoming liquid when heated to a sufficiently high temperature.

**Expansion and Contraction** is the property which a metal has of increasing its length or volume when heated, or decreasing the same when cooled.

**Specific Heat**, or the relative quantities of heat absorbed by metals all compared to the heat absorbed by an equal weight of water when raised through the same temperature.

Metal	Specific Gravity.	Melting-Points (Fahr.).	Tensacity in Tons per Sq. In.
Platinum ... ..	21·53	3110	24
Gold ... ..	19·34	1947	9
Mercury ... ..	13·59	—38	—
Lead ... ..	11·36	620	1·5
Silver ... ..	10·53	1715	18·2
Bismuth ... ..	9·79	507	1·5
Copper ... ..	8·95	1943	12 to 15
Nickel ... ..	8·82	2600	22
Iron ... ..	7·84	2737	18 to 24
Tin ... ..	7·29	449	2
Zinc ... ..	7·14	786	3
Antimony ... ..	6·71	1169	·5
Aluminium ... ..	2·67	1214	7 to 10

In the following table the metals are arranged in the order of their respective qualities, the first in the list being the best:—

Malleability	Ductility	Conducting Power for Heat.	Conducting Power for Electricity.
Gold	Gold	Silver	Silver
Silver	Silver	Copper	Copper
Aluminium	Platinum	Gold	Gold
Copper	Aluminium	Aluminium	Aluminium
Tin	Iron	Zinc	Zinc
Platinum	Copper	Tin	Platinum
Lead	Zinc	Iron	Iron
Zinc	Tin	Lead	· Tin
Iron	Lead	Platinum	Lead
—	—	Bismuth	Bismuth



Table of Weights, Expansion Multipliers, &amp;c.

Metal.	Weight per Cubic Foot, i lbs.	Linear Expansion for 1° (Cent.).	Specific Heat.
Aluminium ... ..	166	·000023	·2143
Brass ... ..	520	·000018	·0939
Copper ... ..	550	·000017	·0951
Gold ... ..	1150	·000015	·0324
Iron ... ..	480	·000013	·1138
Lead ... ..	710	·000028	·0314
Platinum ... ..	1340	·000009	·0324
Silver ... ..	650	·000021	·0570
Tin ... ..	455	·000025	·0562
Zinc ... ..	440	·000029	·0955

**Iron.**

On account of the large supply, cheapness, and its many useful properties, iron ranks as the chief of metals. It is hardly, if ever, found in Nature in its pure state. It is extracted from its ores in the form of cast iron, which, again when subjected to furnace treatment can either be converted into wrought iron or steel.

The main differences in the properties of cast and wrought iron and steel are chiefly due to the presence of carbon in the metal. Cast iron contains about 4·75 per cent. of carbon, steel up to about 1·75, and wrought iron from 0·01 up to about 0·2. The smallest variation in the amount of carbon present considerably alters the properties of the iron.

When iron contains an appreciable amount of sulphur it becomes brittle when heated and is called "hot short." If phosphorus is present the metal becomes "cold short."

The following table gives the percentage composition of several specimens of iron :—

	Sample of Pig Iron.	Sample of Good Iron.	Hot Short	Cold Short.	Low- moor.	Swedish
Carbon ...	3·302	0·080	trace	trace	trace	trace
Silicon ...	2·156	0·170	0·147	0·203	0·150	0·005
Phosphorus	1·258	0·246	0·456	0·480	0·145	0·007
Manganese	2·362	trace	trace	trace	trace	trace
Sulphur ...	0·036	0·010	0·091	0·030	0·010	trace
Iron ...	99·886	99·494	99·306	99·287	99·695	99·988

### Copper.

This is the only metal which possesses a distinctly red colour, and of the ordinary manufacturing metals is, when pure, by far the toughest. It is most durable and an excellent conductor of heat; and on account of the facility with which it can be tinned is largely used in the making of the better-class cooking utensil.

Native copper is sometimes discovered in large masses, but the bulk of the copper of commerce is extracted from ores, cast into ingots and rolled into sheets or bars.

### Zinc.

The chief use of this metal, which is known in the ingot form as “spelter,” is in galvanising sheet iron. Its great advantage is, that while it quickly tarnishes or oxidises, the film so formed is indissoluble and forms a protective coating for the metal beneath.

For rolling into sheets it is essential that the metal should be pure, and also whilst passing through the rolls that its temperature should be between 200° and 250° F.

### Aluminium.

This is a white malleable metal which is a little softer

than zinc. Its chief property is its remarkable lightness, being only about one-third the weight of iron. For sheet metal work its chief drawback is the difficulty with which it can be brazed or soldered.

It is never found in Nature in its pure state. Whilst it is the most widely diffused of all metals on the earth's surface, up to the present difficulty has been found in extracting it from its ores, which is the cause of its comparative dearness.

### **Tin.**

This is a white metal with a slight yellow tinge, and is used principally as the coating metal for tinplates. It is not readily attacked by vegetable acids or meat juices, and this makes it of great value as a coating material for the interior of cooking utensils.

### **Lead.**

Of the ordinary manufacturing metals lead is the softest and possesses the least strength. It is very heavy, being more than four times the weight of aluminium. Its softness renders it particularly suitable for working into the various shapes and forms required by the plumber. It resists the action of sulphuric or hydrochloric acid to a much greater degree than most of the ordinary metals. Nitric acid when strong scarcely attacks it, but when diluted rapidly dissolves the metal. Although lead is practically unacted upon by cold strong acids it is very soon corroded when exposed to an atmosphere containing much carbonic acid. The metal readily flows under pressure in the solid state, hence lead pipes can be formed by squirting from a hydraulic press.

### **Bismuth.**

This is a white metal with a peculiar reddish tinge, and is very brittle. Its chief use is in being added to alloys

of tin and lead, whose melting point it reduces in a remarkable manner.

### Antimony.

This is a bluish-white feathery-looking metal, which is so crystalline that it may be broken and ground up to a powder. Its chief use is for hardening alloys of lead and tin, such as Britannia and Babbit metals.

### Alloys.

Metals are often compounded with each other to obtain various properties not possessed by the metals themselves, such as: (1) Reduction of melting point to something lower than that of one or more of the constituent metals. (2) To increase the strength or toughness. (3) To obtain a different colour. (4) To resist oxidation, or corrosion of sea and other water. (5) To obtain a hardened metallic compound. (6) To facilitate the flow of metal in forming sound castings.

The following is a list of the more important alloys:—

Description	Copper	Zinc	Tin	Properties.
Best Brass ... ..	72	28	—	Very malleable.
Ordinary Brass ... ..	66·6	33·3	—	
Muntz or Yellow Metal	60	40	—	Rolls hot, resists corrosion.
Dutch Metal ... ..	84	16	—	Highly malleable.
Brongé Coinage ... ..	95	1	4	
Gun Metal ... ..	90	—	10	Very tough.
Speculum Metal ... ..	66·6	—	33·3	Takes high polish.
Britannia Metal .. ..	1·8	—	92	and Antimony 6·2.
Babbitt's Metal ... ..	1	—	50	" " 5.
Delta and Aich's Metal	55-60	38-44	with 1·5 to 4 of Iron.	
Pewter Plate ... ..	2	—	89 with Antimony 7 and Bismuth 2	
German Silver ... ..	60	25	with Nickel 15.	
Common Pewter often consists of Lead and Tin alone.				

# CHAPTER XXXIX.

## MENSURATION RULES.

### Circumference of Circle.

Length of circumference = diameter multiplied by 3½,  
or more accurately diameter × 3·1416.

### Area of Triangle.

Multiply the base by half the perpendicular height.

### Area of Circle.

Multiply radius by radius then by 3½. Rules for the ellipse are given in Chapter XXI., and for the cylinder, cone, and sphere in Chapters XII., XXVII., and XXVIII.

### Volume of Frustum of Cone or Pyramid.

Although this has been dealt with in Chapter XII. there is still another important method that can be applied in obtaining the volume of a bucket-shaped or other similar vessel, whether circular or not:—

Let  $a_1$  = area of small end.  
 „  $a_2$  = „ „ large „  
 „  $a$  = „ „ mid-section.

Then volume = height ×  $\frac{a_1 + 4a + a_2}{6}$

Put in the form of a rule it becomes: "Add the areas of the ends to four times the area of the mid-section, multiply by the height, and divide by six."

**Approximate Weights per Square Foot of Iron,  
Copper, and Brass.**

W. G. Number.	Iron. In lbs. per sq. foot.	Copper. In lbs. per sq. foot.	Brass. In lbs. per sq. foot.
1	12½	14	13½
2	11	13	12½
3	10½	12	11½
4	9½	11	10½
5	8¾	10½	9½
6	8¼	9½	9
7	7½	8½	8
8	6¾	7½	7½
9	6¼	7	6½
10	5½	6¼	5½
11	5	5½	5
12	4½	5	4½
13	3¾	4½	4¼
14	3⅞	4	3¾
15	3	3½	3¼
16	2½	3	2¾
17	2¼	2¾	2½
18	2	2¼	2½
19	1¾	2	1¾
20	1½	1¾	1¾
21	1¾	1½	1½
22	1¼	1¾	1¾
23	1½	1¾	1¾
24	1	1	1
25	0¾	0¾	0¾
26	0¾	0¾	0¾
27	0¾	0¾	0¾
28	0¾	0¾	0¾
29	0¾	0¾	0¾
30	...	0½	0½

Sheet Zinc.\*

Approximate Weights of light strengths in Sheets  
8 ft. × 3 ft., showing the equivalent Wire  
Gauge to Zinc Gauge.

No. 4 Zinc	=	about 34 W.G.	...	=	7½ lb. per sheet.
5 "	=	" 33 "		=	8½ "
6 "	=	" 31 "	full	=	9½ "
7 "	=	" 29 "	full	=	11½ "
8 "	=	" 28 "	full	=	13½ "
9 "	=	" 27 "		=	15½ "
10 "	=	" 26 "		=	17½ "
11 "	=	" 24 "		=	20 "
12 "	=	" 23 "		=	22¾ "
13 "	=	" 22 "	full	=	25½ "
14 "	=	" 21 "		=	28½ "
15 "	=	" 20 "		=	32¾ "
16 "	=	" 19 "		=	37½ "
17 "	=	" 17 "		=	41¾ "

Sheet Copper.

Equivalent Gauges and Weights for Sheets 4 ft. × 2 ft.

4 ft. × 2 ft. × 4 lb. = 30 W.G.	4 ft. × 2 ft. × 18 lb. = 18 W.G.
4 ft. × 2 ft. × 5 lb. = 28 "	4 ft. × 2 ft. × 22 lb. = 17 "
4 ft. × 2 ft. × 6 lb. = 27 " easy	4 ft. × 2 ft. × 24 lb. = 16 "
4 ft. × 2 ft. × 7 lb. = 25 "	4 ft. × 2 ft. × 28 lb. = 15 "
4 ft. × 2 ft. × 8 lb. = 24 "	4 ft. × 2 ft. × 32 lb. = 14 "
4 ft. × 2 ft. × 9 lb. = 23 " easy	4 ft. × 2 ft. × 36 lb. = 13 "
4 ft. × 2 ft. × 10 lb. = 22 " "	4 ft. × 2 ft. × 40 lb. = 12 "
4 ft. × 2 ft. × 12 lb. = 21 "	4 ft. × 2 ft. × 44 lb. = 11 "
4 ft. × 2 ft. × 14 lb. = 20 "	4 ft. × 2 ft. × 50 lb. = 10 " , "
4 ft. × 2 ft. × 16 lb. = 19 "	

## CHAPTER XL.

## ANNEALING, WELDING, ETC.

**Annealing.**

IN the operation of rolling, hammering, or drawing, metals become hard and brittle; and to avoid fracture in further working the sheets or plates, it is essential that these should be softened, or annealed, as it is called.

**Sheet iron** or steel is made by passing pieces of the metal, in almost a white-hot condition, backwards and forwards through powerful rolls and rolling down to the required thickness. After rolling, the sheets are very hard, and have to be kept in an annealing furnace for several hours to bring them back to the soft state. The length of time they are in the furnace, and the slowness of cooling, more or less determine the degree of softness of the sheet. When the sheets are placed in batches in the furnace and heated in an uncovered state, they are said to be **open-annealed**. For some purposes, however, batches of sheets are placed in iron boxes and annealed without coming in contact with the atmosphere or the furnace flames; these are called **close-annealed** sheets. The open-annealed sheets have more scale on them than the close-annealed sheets, the latter, of course, having a much smoother surface. To obtain a good smooth surface, sheets are sometimes run, when cold, through smooth rolls after they are close-annealed; and this quality of iron is called **cold-rolled-close-annealed**.

**In stretching** the edge of an article, throwing off a flange,



or in raising, hollowing, stamping, or spinning, some judgment must be exercised as to the suitable times for annealing. One kind of a job may only require to be softened once, whilst others may have to be annealed several times before the sheet metal can be worked with safety up to the required shape. In any case, care ought always to be taken against working a metal up to the splitting or cracking point for the want of annealing.

**In annealing iron** or steel the highest degree of softness is obtained when the sheet or plate is allowed to remain red hot as long as possible and to cool out very slowly. In thin sheet metal care should be taken that the edge of the sheet is not "burnt" or over-annealed. Even if a piece is not burnt out the edge may be got to a white heat, and this part will break away when being hammered.

**Copper** becomes soft when made red hot and allowed to cool out slowly in the air or plunged into water. When cooled out in water there is the additional advantage that the surface of the sheet is cleaned in the process by the removal of the scale in the water. This is especially the case if the surface of the copper is sprinkled with common salt before the sheet is made red hot.

**Brass** is annealed by gradually heating, and then being allowed to cool out slowly.

**Zinc** gets rather brittle at low temperatures. This is well known to those who work sheet zinc during winter in a cold workshop. For safe working during cold weather, sheet zinc should be warmed so that it can just be handled, and this is especially so if any sharp bends or edges have to be made.

In working upon any part of a sheet or plate that is to be used in a pipe or vessel that is to be subjected to a pressure, the greatest care must be taken that no part of the metal is left in a stressed condition, either through hammering or local heating. Serious results sometimes happen through want of thought in this direction. The metal can generally be brought

to a proper condition by careful heating with the blowpipe or furnace, not only the parts that have been worked, but also the surrounding metal that may have been affected.

Every time a piece of metal is made red hot, whilst in contact with the atmosphere, fresh scale forms on its surface. This is due to the oxygen in the air combining with the metal to form an oxide. It is therefore evident if we require a metal not to scale or waste during annealing, it must be kept out of contact with the atmosphere, and this is in many cases an exceedingly difficult thing to do. Small articles in iron may be covered with rust or oxide, and copper may be buried in ash dust. Furnaces for large work are now being constructed in which metals can be heated out of contact with the atmosphere.

**Theory of Annealing.** Why metals become hard when worked, or why they become soft under heat treatment, are difficult questions to answer. Or, again, why a metal like steel becomes hard when plunged into water, or copper under the same treatment becomes soft, is no easy task to solve. Sufficient to say that these matters are now being carefully investigated, and at the no distant future a full scientific explanation will be forthcoming. We can, however, imagine that under hammering or rolling the particles of the metal become pushed or crushed into unnatural positions, and then the metal is strained or hard. When heated, and whilst the metal is in the soft state, we may suppose that the particles then assume their natural position, and the metal comes back to its normal condition of softness.

### **Autogenous Welding.**

The welding together of two pieces of the same metal without the introduction of a solder is termed "autogenous soldering." The term, therefore, has a very restricted meaning, and up to the present can only apply to the welding of iron

or steel, "lead burning," and, to a slight extent, cast iron and copper. It is true that cast iron, aluminium, and some alloys can be fused together, but these require the aid of a flux.

Autogenous welding permits the fusing together of bars or plates of iron or steel, from the thinnest sheet up to almost any thickness of plate that is used in the boiler shop. With great care it is possible to make the welded portion as strong as the solid bar or plate, but generally it is the safest plan to assume that the welded part will be slightly weaker, say to the extent of about 5 per cent. of the solid plate.

Of recent years the process of autogenous welding by the oxy-acetylene method has come rapidly to the front, and has now a very wide application.

There are two systems in operation—namely, the "high pressure" and the "low pressure." In the former case, where dissolved acetylene is used, the two gases are under high pressure in cylinders; and for use the acetylene is reduced to a pressure of about  $5\frac{1}{2}$  lb. per square inch before it passes to the blowpipe, the oxygen being regulated to give the correct flame. This latter is judged by the appearance of the flame, and with a little experience the proper condition of the blowpipe flame for welding can be arrived at.

To ensure success, the work should be properly prepared before attempting to weld. When it is desired to make a butt joint on plates over  $\frac{1}{8}$  in. in thickness, the two edges of

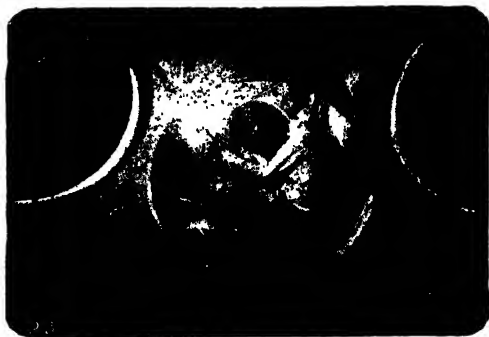


the plates should be bevelled so that when they come together a "V" is formed, that should be as wide as the plates are in



Shows a welded Steel Petrol Tank.

thickness. The complete removal of any rust or scale is also essential. The feeding metal, with wrought iron or steel, should be, if possible, shearings from material similar to the



Repairs to Marine Boiler Furnace by Acetylene Process.

metal worked upon, and should never be of greater section or diameter than the thickness of the work ; and in case of heavy

work, should not be greater than  $\frac{1}{4}$  in. diameter or  $\frac{3}{16}$  in. square. In practice, Swedish iron wire is very commonly used as a filling-in medium, which, in such cases, accounts for the loss of strength when dealing with boiler plates.

The following table will give some idea of the gas consumption per foot run, on different gauge iron or steel, and the rate at which work can be carried out:

Thickness of Plate.			Consumption of Acetylene, cubic feet.	Consumption of Oxygen, cubic feet.	Speed of work in foot run of weld per hour.
Wire Gauge.	Inches.	mm.			
20	·04	1·0	1·8	2·25	50
16	·06	1·5	2·7	3·50	40
14	·08	2·0	3·6	4·50	35
12	·10	2·5	5·4	7·75	30
10	·12	3·0	8·0	10·00	24
8	·16	4·0	12·5	15·70	18
	$\frac{1}{4}$	5·6	18·0	22·00	14
	$\frac{5}{16}$	7·8	27·0	33·00	10
	$\frac{3}{8}$	9·10	36·0	44·00	7

When the metal is over  $\frac{3}{8}$  in. in thickness, the gas consumption, per foot run, increases rapidly, and the speed of work falls similarly.

When acetylene, in either the high or low pressure system, is used with oxygen, in a properly designed blowpipe, it splits up into its component parts—hydrogen and carbon—at the base of the flame, carbon only taking part in the burning, due to the fact that hydrogen will not combine with oxygen at the temperature carbon will; consequently the hydrogen remains free and forms a protecting zone at the blowpipe tip, where the carbon is burning. The high flame temperature obtained, combined with the fact that there is a zone of free hydrogen, renders the flame very reducing and extremely

suitable for many operations, which would otherwise have to be carried out by a more costly and probably less efficient method, and which would, in many cases, be altogether impracticable. The temperature of the oxy-acetylene flame is very high, being about 6,350° F.

To ensure the complete combustion of acetylene, theoretically 2.45 volumes of oxygen are required to one of acetylene, but in actual practice it is found that the proportions vary



• Repairs to a Steamer by Oxy-Acetylene Welding.

between 1.6 to 1.0 and 1.0 to 1.0, the lower figure being round to be correct when heavy work is done with the high-pressure system, and the higher when working with the low-pressure system or the high-pressure system on light materials.

The autogenous process can be used for the welding of

bicycle, motor-car, and aeroplane frames, and in many cases act as a substitute for rivets; the welding and repairing of boilers, tanks, ships, etc.; the filling in of parts that have been worn or corroded away; and the repairing of all kinds of cracks.

In the repairing of cracks in riveted joints or other work that is held tight in position, it is important that part of the work around the crack should be loosened by unriveting, so as to allow for the expansion and contraction that takes place when the broken portion is passing through the welding



Wrought-iron Scroll Work, built up by Oxy-Acetylene Process.

process. It is also important that the parts all around the repaired portion should be carefully heated up so that as far as possible no undue strain shall be placed upon, or any stresses left in, the plate or bar.

The illustrations shown will give some idea of the range of work that can be carried out with the oxy-acetylene welding blowpipe.

### Cutting Metal with Oxygen.

In addition to welding, as explained above, acetylene can also be used as the heating agent in a special blowpipe for

oxygen cutting. The blowpipe is so arranged that a separate jet of oxygen may be discharged through the centre of the blowpipe flame when the metal is heated up to melting-point. This immediately produces combustion of the metal with the resulting formation of oxide. The jet of oxygen is made sufficiently strong to blow away this iron oxide in front of it, with the result that a clean, narrow cut is effected through the metal at a speed of travel which is comparable with hot sawing. The metal on each side of the cut is neither melted nor injured in any way, as the action proceeds too rapidly for the heat to spread. The cutting may be made to follow any desired line or curve as required.

Some idea of the rate of cutting can be gleaned from the fact that  $\frac{1}{2}$ -in. plate can be cut at the rate of 1 ft. per minute, and boiler plate, of  $1\frac{1}{2}$  in. thickness, being cut at about one-half this speed.

The proportionate consumption of acetylene to that of oxygen varies from 25 per cent. for the thinnest section of plate to 10 per cent. for the thickest section of plate.



# CHAPTER XLI.

## MISCELLANEOUS PATTERNS.

### Gear Case for Mitre Wheels.

THE making of a sheet metal covering to act as a guard for bevel wheels is not by any means a difficult matter, the chief consideration being the setting out of the patterns to work up

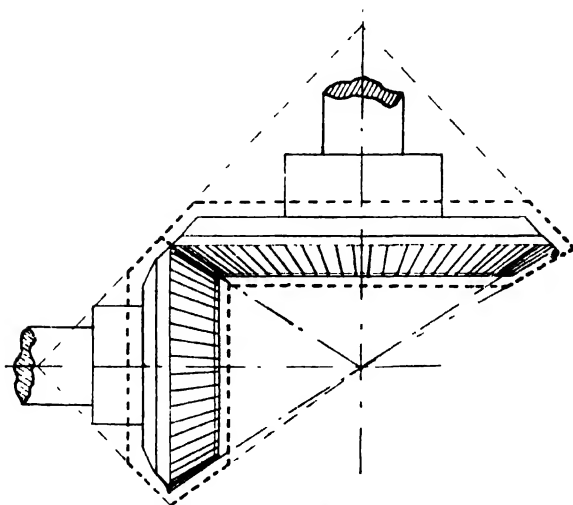
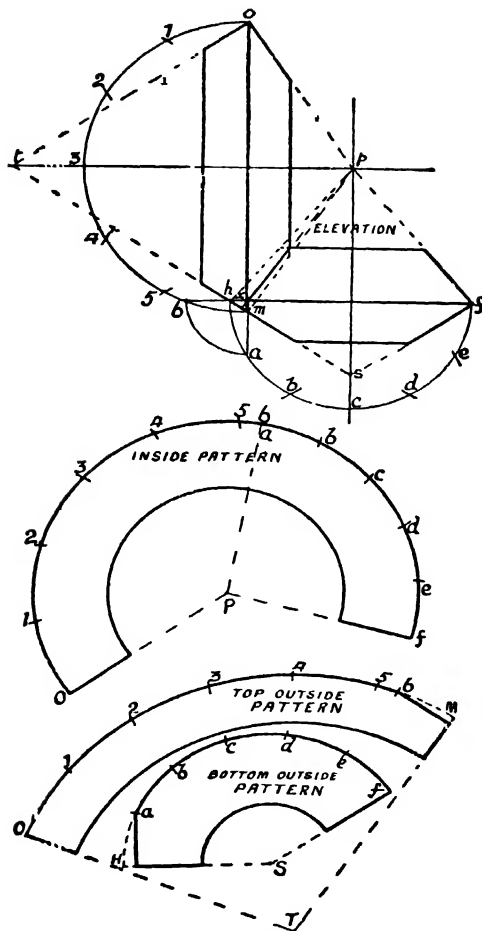


FIG. 339.

exactly to the required shape. A view of a pair of wheels is shown in Fig. 339, the thick dotted lines representing the



gear case. A little consideration will show that the guard is formed from the surfaces of four cones, arranged in such a way to intersect or cut into each other so as to give the necessary opening for the two wheels to gear together. The setting out of the patterns is fully explained by the diagrams on Fig. 340.

The case is made in two equal halves, these, when put over the wheels, being fastened together with slip wire hasps at *f* and *o*. It will thus be seen that each half of the cover is formed of four half frustums of cones.

The inside cones have a common apex at *p*, and overlap or intersect each other so as to give the opening for the two wheels to come together. Thus, the base of one cone is *f h* and the other *o m*, these crossing at *x*. In setting down the bases of the cones the sizes of these must be arranged so as to bring the lines *x 6* and *x a* equal in length, these giving half the width of the opening of the cones at the bases.

In marking out the pattern for the insides of the case, *P o* on the pattern is made equal to *p o* on the elevation; the lengths *0 1*, *1 2*, etc., up to *6*, being set off from the top semicircle, and the lengths *a b*, *b c*, etc., from the bottom semicircle.

The patterns for the outside are marked out in a similar manner, *T o* and *S f* on the patterns being equal, respectively, to *t o* and *s f* on the elevation. The girth around each one will be the same length as that of the corresponding semicircle in the elevation. The straight lines at the ends are obtained by seeing that *M 6* and *H a* on the patterns are respectively the same lengths as the arcs *m 6* and *h a* on the elevation, the lines then being drawn square to the outside lines of the patterns. It should be observed that these two lines come the same length if the patterns are marked out correctly.

Half discs to put into the backs and fronts of the casing

will be required, but patterns for these are not shown. Allowances for jointing must be added to the patterns to suit the method of jointing adopted.

### Square Cover or Dome of Semicircular Section.

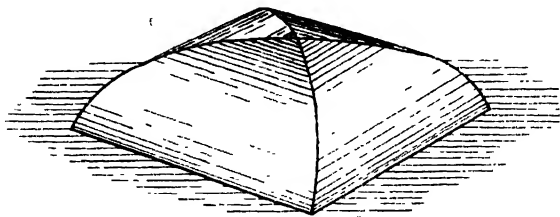


FIG. 341.

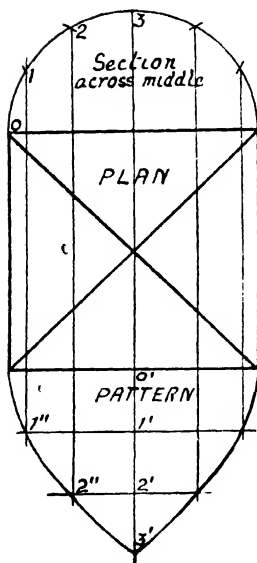


FIG. 342.

A very effective-looking cover can be made up out of four pieces of sheet metal to the shape as shown in Fig. 341. The shape is semicircular in both directions.

The pattern is marked out as seen in Fig. 342. A semicircle is described on one side of the plan, one-half being divided into three equal parts 0, 1, 2, and 3. For the pattern, the lengths  $0' 1'$ ,  $1' 2'$ , and  $2' 3'$  are made equal to the lengths of the correspondingly numbered arcs on the section; lines drawn through each point across and, on to these, lines run down from 1 and 2; thus the points  $1''$  and  $2''$  are obtained. The points so found are carefully joined up with a free

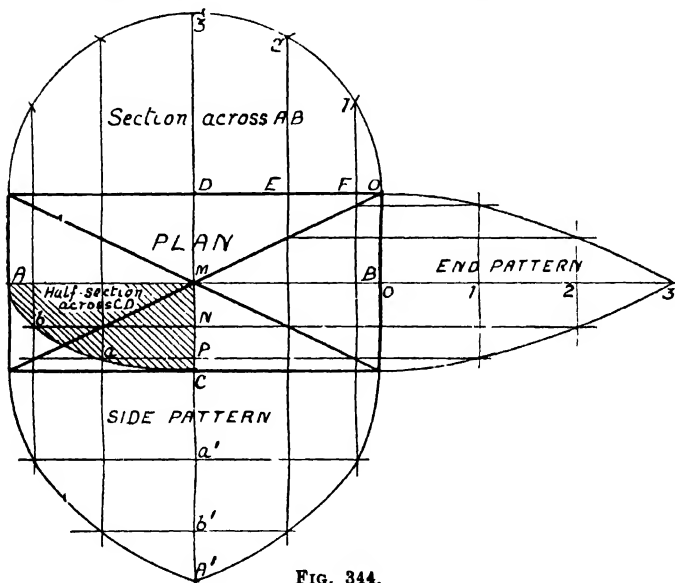
flowing curve; the other side of the pattern being obtained in the same manner.

It will readily be seen that all the lines required for the setting out of the pattern can be obtained by drawing only one-eighth of the plan and half of the section. The full plan has been drawn in here to better explain the method. The joints can be made either by soldering, knocking-up, or any other way as required.

### Rectangular Cover of Circular and Elliptical Sections.

The pattern for this is shown marked out on Fig. 343. The side pieces are quarter circle in section, and to join on to these, if the joints are to be diagonal as in plan, it will be necessary for the end pieces to be a quarter of an ellipse in shape. The pattern for the side is set out exactly as for the square cover. Before the end pattern can be struck out it is necessary to draw the shape of the half section as shown. This is done by running lines down from 3, 2, and 1 on the semicircle to the diagonal line on the plan; then drawing across and marking up M A to equal D 3, N b to equal E 2,

and P  $\alpha$  to equal F 1. Joining these points up will give a quarter of an ellipse. For the end pattern the girth line C  $\alpha'$   $\delta'$  A' must be set out to equal in length the parts with the corresponding letters on the quarter ellipse. Lines are drawn across from the points, and others to meet these from the



**FIG. 344.**

semicircle, and thus points on the pattern curve obtained. These being carefully joined will give the pattern as required.

In Fig. 344 it will be seen that the semicircular section runs lengthways of the cover; the setting out of the two patterns is, however, exactly the same as in the last case.

### Conical Pipe on Spherical Dome.

If the conical pipe has to fit on the middle of the spherical dome, it will at once be seen that the cut on the end of the

cone must be square to its centre line. But if the conical pipe fits on the side of the dome, as in Fig. 345, then the setting out of the pattern becomes a much more difficult matter.

To set out the pattern for the latter case, it will be necessary to first of all obtain points on the elevation of the joint line. To do this the principle adopted is to imagine horizontal cuts taken through the cone and sphere. These sections would of course be circles, and where they intersect each other would give points on the joint line. The arcs shown on Fig. 345 represent parts of the section circles. Thus, to obtain one point: With centre *c* (on the centre line of sphere) and radius *c b*, the arc *b e* is drawn; then with centre *d* (on the centre line of the cone) and radius *d a*, the arc *a e* is drawn;

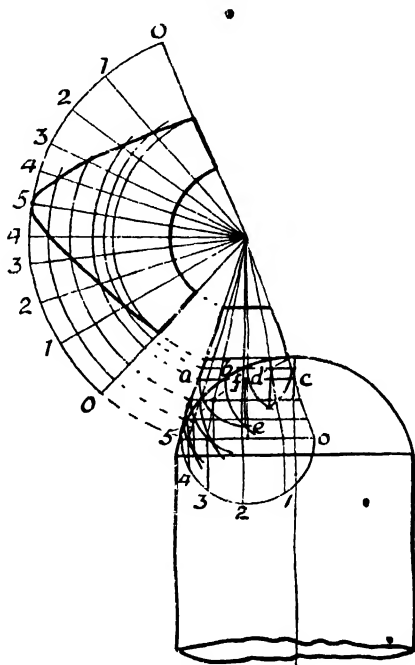


FIG. 345.

from the point *e*, where the two arcs intersect, a perpendicular is dropped on to the line *a c*, giving *f*, this being one point on the joint line. In the same manner, as many other points as are required can be obtained. Through each point so found, a line from the apex of the cone is drawn down to the base,

and then from the base on to the semicircle as shown. The lengths of arcs on the semicircle are then set around for the girth of the pattern curve, as 0, 1, 2, etc., and the radial lines drawn; these latter are then cut by swinging the lengths

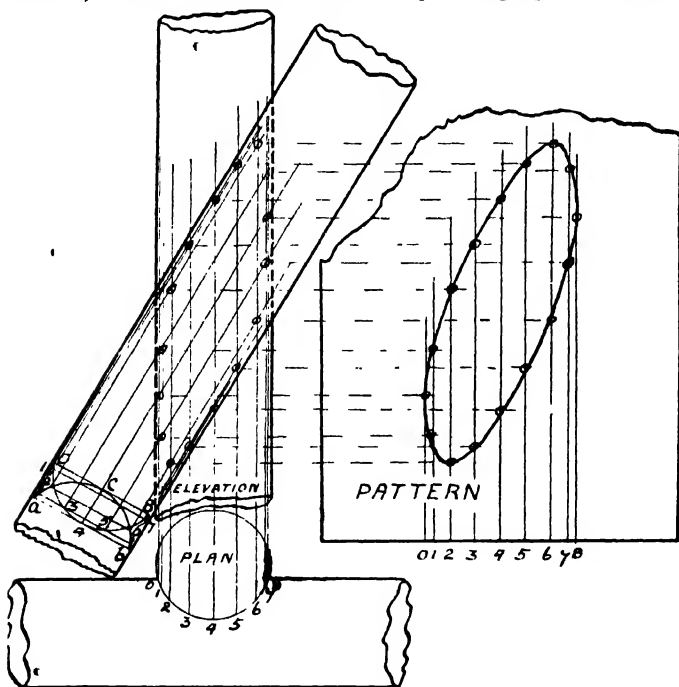


FIG. 346.

around from the side of the cone. When the points so found are joined up, the pattern is complete.

### **Cylindrical Crossed Tubes**

A somewhat interesting case of pattern-cutting is that shown in Fig. 346. It will be seen that the tubes cross and



cut part way into each other, and as both pipes are the same size, the shape of the hole in each pipe will be the same.

The setting out of the pattern is now explained. The part of the circle, 0 to 8 in plan, which shows the distance the pipes cut into each other, is divided up into any convenient number of parts; the same being done with an exactly similar arc on the pipe in the elevation. An arc (*a c b*) of the same size and shape is drawn in the reverse direction as shown. Lines 7 1, 6 2, and 5 3, are drawn across to cut this arc, and from the points of intersection lines are drawn along the pipe; where these meet the lines on the vertical pipe, will give points on the elevation of the joint line. The girth on the pattern is laid out from the numbered arc on the plan; lines run up, and others drawn across from the elevation as shown, and thus points on the hole obtained.

The holes on the two pipe patterns will, of course, be the same shape if the pipes are of equal diameter; but if one pipe is larger than the other, the holes will be of different shapes and require to be set out separately. The same method, however, as shown for equal pipes, can also be applied to those of unequal diameter.

### Curved Square Hood.

A hood with curved back, throat, and sides, as shown in Fig. 347, can have its patterns marked out with very little trouble if the method as shown on the diagram is followed.

For the cheek pattern, the lengths 0 1, 1 2, etc., are made equal in length to the arcs with the same numbers on the end elevation, and the width projected down from the side elevation, these points then being joined up. The curve *a 4* at the top of the pattern will be the same as that on the elevation above. The back pattern lengths are taken from the side elevation, lines drawn across, and these cut off to the required

lengths by projecting down from the end elevation. The throat pattern is obtained by taking the lengths from the throat in the side elevation, and the widths across from the end elevation.

The four parts can be joined together by either knocking-

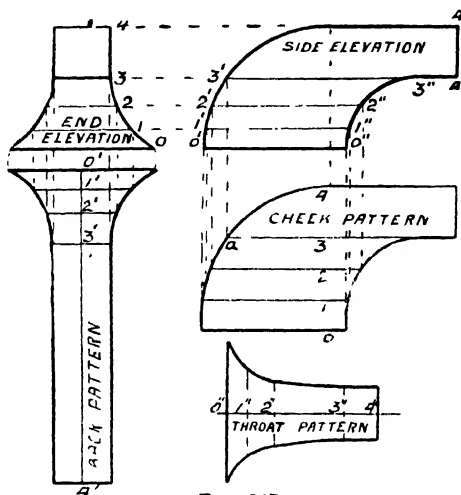


FIG. 347.

up, riveting, or any other method as required, the necessary allowances being put on the patterns.

### • Offside Conical Crosspipe in Conical Tube.

Perhaps one of the most peculiar and difficult patterns to mark out is that for a conical pipe which fits inside another conical pipe, and whose centre lines do not meet and are also inclined to each other. The position of the pipes can be best understood by reference to the plan and elevation in Fig. 348.

In this case, and in most others, the main difficulty lies in

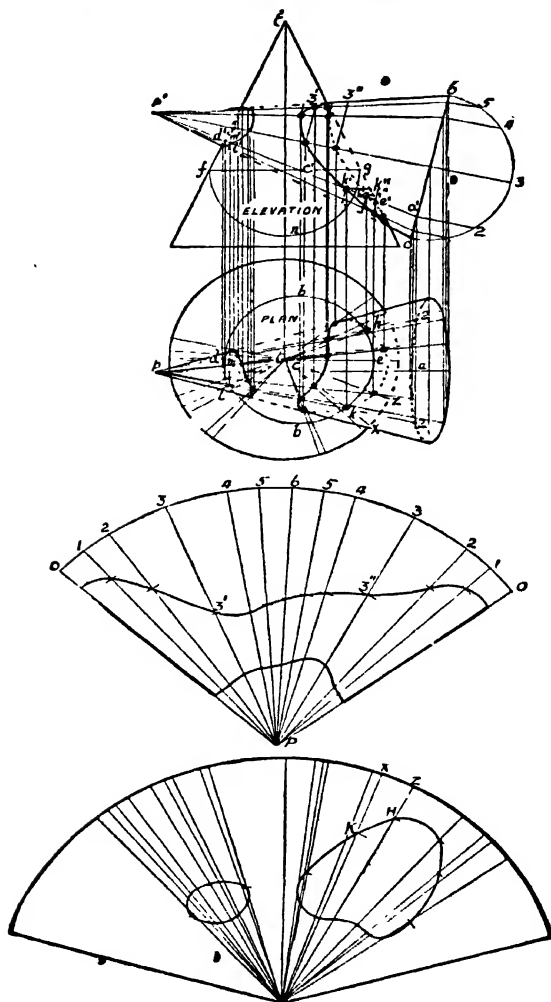


FIG. 348.

obtaining points on the curves of intersection of the two pipes ; as when this is accomplished very little trouble is experienced in afterwards laying out the patterns.

To obtain points on the joint curve several methods can be used. In this case the idea is to take cutting planes which all pass through the apex  $p'$  of one cone, and thus give triangular sections ; the sections of the other cone being elliptical. Where the pairs of triangles and ellipses intersect will give points on the curve of interpenetration. It will be as well to explain how to obtain one set of points. A semicircle is described on the base of the inclined cone and divided into six parts. Take the point marked 2. A line is drawn square to the base, giving  $a'$ , and this point joined to  $p'$ . A projector is drawn from  $a'$  to the centre line of the cone in plan, giving  $a$  ; then  $a$  2 in the plan is made equal to  $a'$  2 in the elevation, the points marked 2 being joined to  $p$ . The line  $d' e'$  is bisected and a horizontal line ( $f g$ ) drawn through its middle point  $c'$ . On  $f g$  a semicircle is described, and a perpendicular ( $c' n$ ) dropped from  $c'$  on to it ; the length,  $c b$  in the plan, being made equal to  $c' n$ , and  $d$  and  $e$  obtained by projecting down from the corresponding points in the elevation. Through the points  $d b e b$  an ellipse is drawn, or such parts of it as are required to cut the lines marked  $p 2$ . Thus four points,  $h k l m$ , are found, and these projected up to the elevation. In the same manner any other number of points on the joint curve can be obtained.

To strike out the pattern for the outside cone : Lines are first drawn from  $t$ , in the plan, through each point on the curves—thus, to show two,  $t x$  and  $t z$ —and from the lengths of arcs obtained, the girth curve on the pattern is laid out and radial lines drawn, as shown by  $T X$  and  $T Z$ . The points on the pattern holes are found by running lines from the points on the elevation of the joint curve to the outside of the cone ; thus, the lengths  $T K$  and  $T H$  on the pattern are respectively

equal to  $t' k''$  and  $t' h''$  on the elevation. In a similar way all the other points required are obtained.

The pattern for the inclined cone or inside tube is set out in the usual way, lines being run out to the outside line of the cone and lengths taken off. Thus,  $P 3'$  and  $P 3''$  on the pattern are made equal in length to the corresponding lines  $p' 3'$  and  $p' 3''$  on the elevation.

In complicated work of the above description, the setting out must be done as accurately as possible if it is desired that the parts shall fit neatly together.

## CHAPTER XLII.

## THE CORROSION OF METALS.

## NON-CORROSIVE OR RUSTLESS METALS.

WHEN one thinks of the hundreds of thousands of tons of steel, copper, zinc, tin, lead and other metals that are put into use year by year, it is interesting to know what becomes of them ultimately.

If we follow out the life-story of almost any piece of metal, it means that, in the end, it goes back again to the mother earth from which it was originally obtained.

It would seem that Nature, in all the materials she has at command, has one steady aim in view, and that is to bring about a condition of equilibrium or rest. The operations of man, on the other hand, are in the direction of resisting her workings and to keep things going in the way he wants and for his own purposes. In the end, however, Nature will inevitably conquer, and all that man does is to keep her in check for as long a period as he possibly can.

Thus, iron in the form of ore or oxide of iron is delved from the bowels of the earth by man's exertions. It is made up into sheets, bars, wire, etc., goes out to fulfil its purposes, and then returns from whence it came, but in a much more distributed manner. Hence, so far as the earth is concerned, all man's efforts result in the mixing together of its ingredients in a little quicker time and a somewhat more uniform manner than is done directly by Nature herself.

The inevitable law of Nature, by which things are ever changing, holds good with reference to metals as with other elements, whether it be a piece of galvanized sheet iron, a gold chain, the rocks on the shore, or the trees in the forest, they are all subject to the same law of change and decay.

Amidst all this change, however, there is one consoling thought, that is, the way in which Nature carries out her secret processes of conservation, by which not a single atom of matter or a unit of energy is lost or annihilated in her operations.

A great deal of investigation work has been carried out to find the causes of the decay or corrosion of metals, and the ways by which this action may be resisted.

Corrosive action is generally attributed to the effect of air or moisture upon the surfaces of the metals, but the peculiar thing is that metal may be kept in an uncorroded condition in a dry atmosphere, also in pure water when it

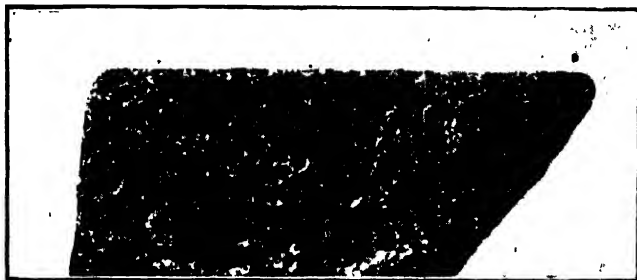


FIG. 349.

is free from air, for very long periods. It would appear, therefore, that there is some other action brought into play, and this fact is confirmed in the result of a great number of experiments that have been made during recent years.

It has been found that there are many things that effect the wasting of metals. Generally it is considered that any condition of the metal that sets up what is known as electrolytic action of even the feeblest state, is that which is most conducive to the corroding of the material.

When two dissimilar metals, such as copper and zinc, or iron and tin, are brought into contact at one part, with a little moisture between the other parts, a slight electric current

is generated, which in its action accelerates the decay of one of the metals. Indeed, it is not only true that an electric current is set up when two dissimilar metals are in contact, but it is also true that electric action takes place even between

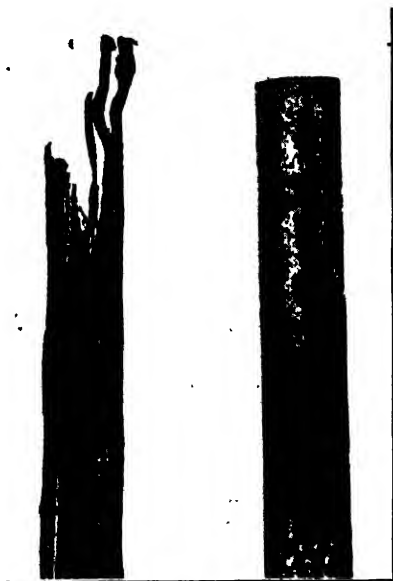


FIG. 350.

the rust or scale on iron, and the iron itself. The same phenomenon also takes place in a single metal when one part of it is in a different condition to another. Thus, if a piece of steel has one part hammered and the other unhammered, this difference of state will set up electrolytic action between the two parts, and thus accelerate corrosion. In the same manner an annealed steel sheet will last longer when exposed to the atmosphere, whether galvanized or not,



than one that is in the strained condition as it comes from the rolling mill.

Fig. 349 is a photograph, half full-size, of a piece of hoop-iron that has lain on the sea-shore for some months with salt-water washing over it at every tide, and then left exposed to the atmosphere. Examination shows that it is covered completely with pit marks, these respectively being the little centres of electrolytic action caused by the scale or impurities in the metal, assisted by the salt-water and air, and in this manner it is thus eaten away.

Fig. 350 is a full-sized photograph of a rod of wrought-iron both before and after treatment in acid. It will be noticed that the acid has a selective action on the bar, some parts being attacked much more rapidly than others. This selective action is again due to the generation of local electric currents which results in the more impure parts of the bar being dissolved away at a quicker rate than the purer parts.

In passing, it might be mentioned that the fibrous nature of wrought-iron is due to one part being more impure than another and also to the included pockets of slag; these, in rolling or drawing, setting up laminations or fibres. Hence a sheet that is bent along the direction of rolling is always weaker than when bent across the fibres.

To watch the growth of corrosion in its very earliest form under the microscope is exceedingly interesting. Very minute specks or nuclei of corrosion appear and then gradually develop into larger areas; the corrosion being accelerated by the products of its own growth.

In Fig. 351 the commencement of corrosion is shown on a piece of wrought-iron. This was carefully polished, etched, and magnified 400 diameters. The streak across the picture represents an impurity in the iron, and it will be noticed that the corrosion is taking place right along the edge of the impurity, which is shown by the black fringe. Incidentally,

this photograph is also a good illustration of the masonry-like formation of the crystals that go to make up the mass of iron, these being carefully dovetailed into each other, as will be seen by the boundary joint lines.

A further illustration of the growth of corrosion is shown by the micro-photographs, Figs. 352 and 353. of a piece of



FIG. 351.

gun-metal which has been magnified 100 diameters. This alloy is composed of about 9 per cent. of tin and 91 per cent. of copper. The dark parts of Fig. 352 really represent a compound of copper and tin, the light areas in between being practically pure copper. Fig. 353 is a reproduction of the same surface after the polished alloy had been exposed to the atmosphere for some time. It will be observed that selective corrosion has taken place on the small copper-tin areas, this being shown by the very dark spots. The pure copper portion has remained unaffected.

Corrosion of metals or alloys is sometimes arrested by what is known as the "passive state," which means to say that certain chemicals or peculiar constitution of the metals appear to make them inert, or in other words, oppose the generation of the weak electric currents which cause corrosion or wasting. In some cases corrosive action may set up "polarization," this being the covering of the metal surface

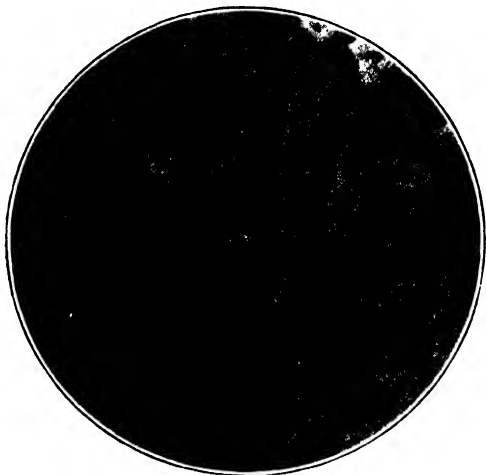


FIG. 352.

by minute bubbles of a gas or with a particular kind of oxide the generation of the small electric current is opposed or stopped, and corrosion ceases. This is one of the reasons why the acid cleaning of steel is always improved when either the article or the acid is kept in continual motion; the small bubbles of hydrogen being dislodged, thus allowing the acid to have free action.

The corrosive action of metals is usually increased by increase of temperature, other conditions being equal. It

is also rather interesting to know that light affects the rate of corrosion of iron and steel, but, whilst no very definite information has up to the present been obtained as to its exact effect, experiments go to prove that a metal wastes quicker when light falls upon it than when kept in the dark.

Small insects and bacteria under some conditions, it has been found, play a part in corrosion. The so-called Iron



FIG. 353.

Bacteria, for instance, having the power to absorb iron from water and assist in building up the deposits of corrosion on pipes, tanks, etc.

### **Non-Corrosive or Rustless Metal.**

Many attempts have been made to bring out a metal suitable for sheets and plates which would be non-corrosive in character, but no great degree of success has been attained up to the present time.

Steel containing Nickel and Chromium has been rolled into plates and this in service offers a good deal of resistance to corrosion, but on account of its hardness it is difficult to roll it into thin sheets, in addition to which the cost of production makes it prohibitive for anything like general use.

A somewhat remarkable alloy known as Monel Metal has been used in America for some time, and is now placed on the market in this country. Its composition varies, being somewhat as follows:—

Nickel	..	..	..	..	60% to 67%
Copper	..	..	..	..	28% to 33%
Iron	..	..	..	..	2% to 6.5%

In addition to the above the alloy occasionally contains a small quantity of Aluminium or other metals. • •

It is a light coloured, fairly soft alloy, and certainly offers considerable resistance to corrosion and also to the action of acids; but nevertheless dissolved by the latter.

Another metal known as Rustless Steel has come into use during recent years for cutlery purposes. This metal contains about 12% Chromium and 1% of Nickel. When the surface is brightly polished it offers considerable resistance to staining or rusting, but if the surface is at all rough then corrosive action is slowly set up.

A further metal which has come into use in recent years is Ferro-Silicon cast iron, which is used for vessels and pipes in and through which acid has to be passed. This metal varies very much in composition, and its resisting properties depend very largely upon how the metal is made. •

Another acid resisting metal is a special kind of Phosphor Bronze, which can be used for tools, pipes, etc., that have to be submerged in acid. For this purpose this metal has very great advantages and lasts a considerable length of time.

## CHAPTER XLIII.

## SHEET AND PLATE METAL WORKING MACHINES AND TOOLS.

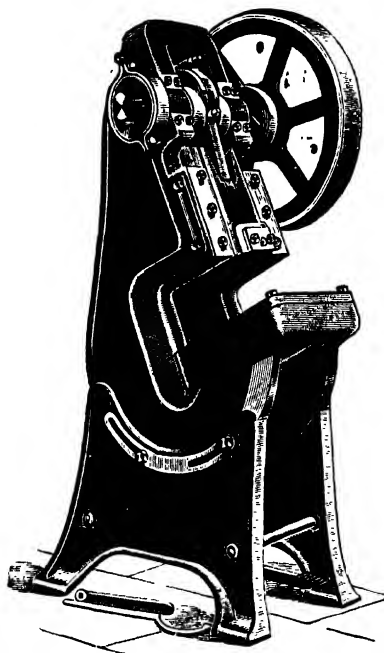
THE machines and tools used in sheet and plate metal work are of almost infinite variety, especially in the former class of work.

For plate work the machines usually used are those for straightening, punching, shearing, planing, rolling, drilling, riveting, together with hydraulic presses for flanging, and a variety of pneumatic and electrically driven tools.

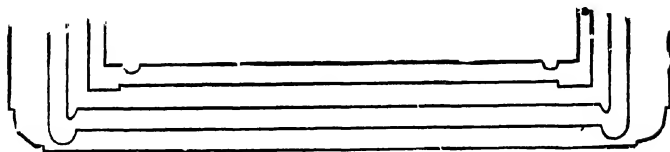
In sheet metal work the chief machine is perhaps that of the press, in which blanks of almost any shape and size can be cut out, and objects pressed or drawn into any form as required.

The spinning lathe, too, is used for a great number of operations in light work, either in trimming, flanging, bulging, burnishing, beading, curling, or wiring of stamped or drawn articles. Also, with suitable tools, hollow circular objects can be spun right up into shape from the flat disc.

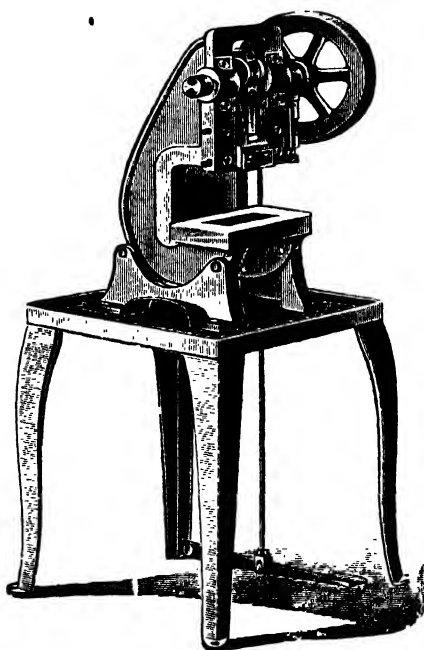
A few of the more important machines used by sheet metal workers are shown in the following pages, also several bench tools, in addition to those *already* given in the former chapters.



Inclined Power Press for Cutting, Piercing and Forming.

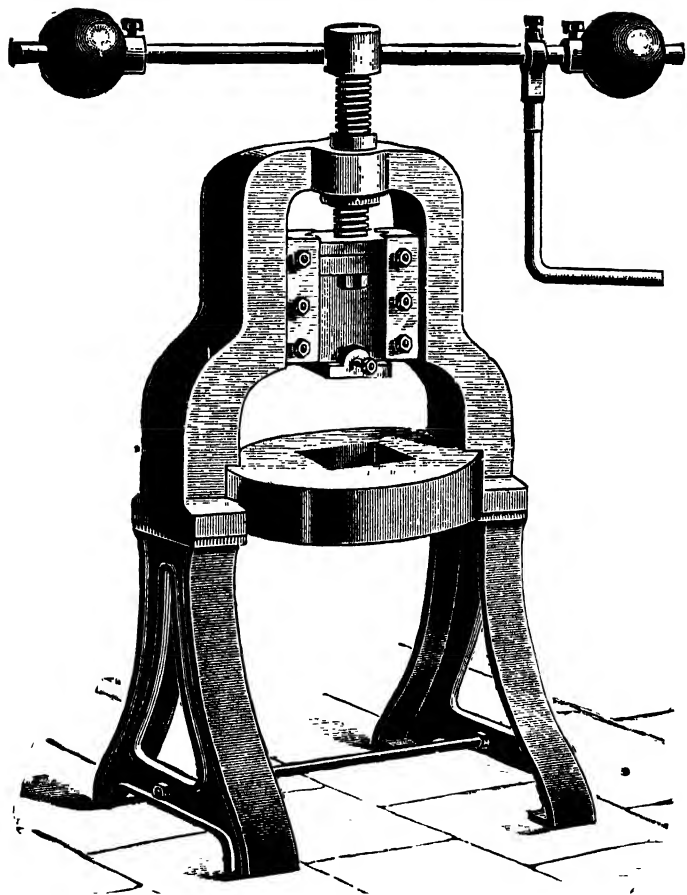


Sections as formed in the above Press.

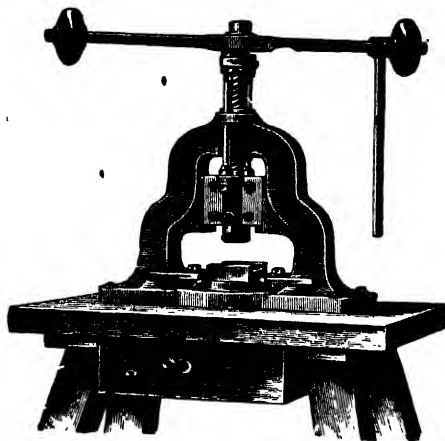


Power Press for Small Articles.

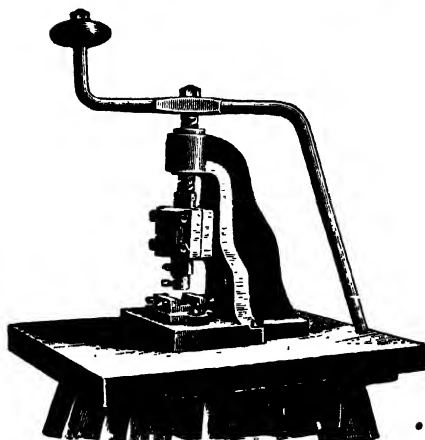




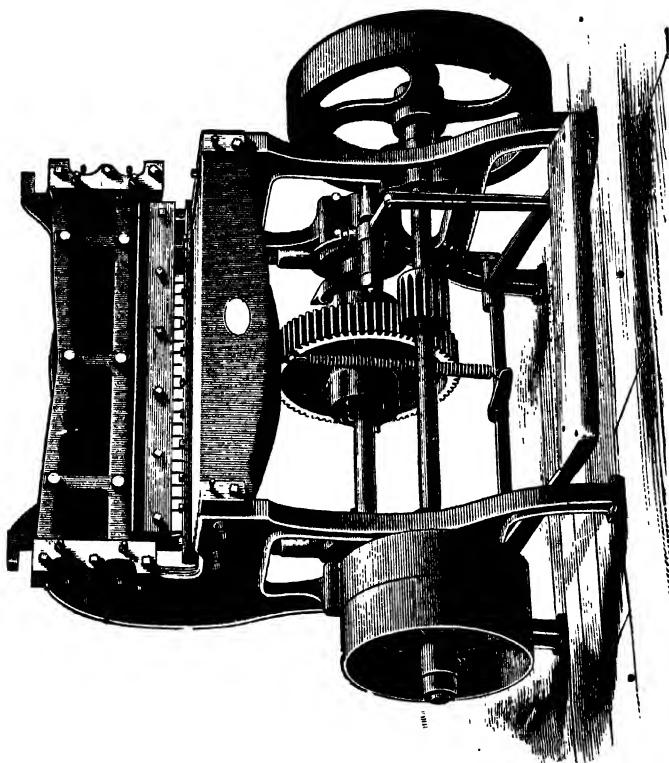
Double-Arm Screw Press.



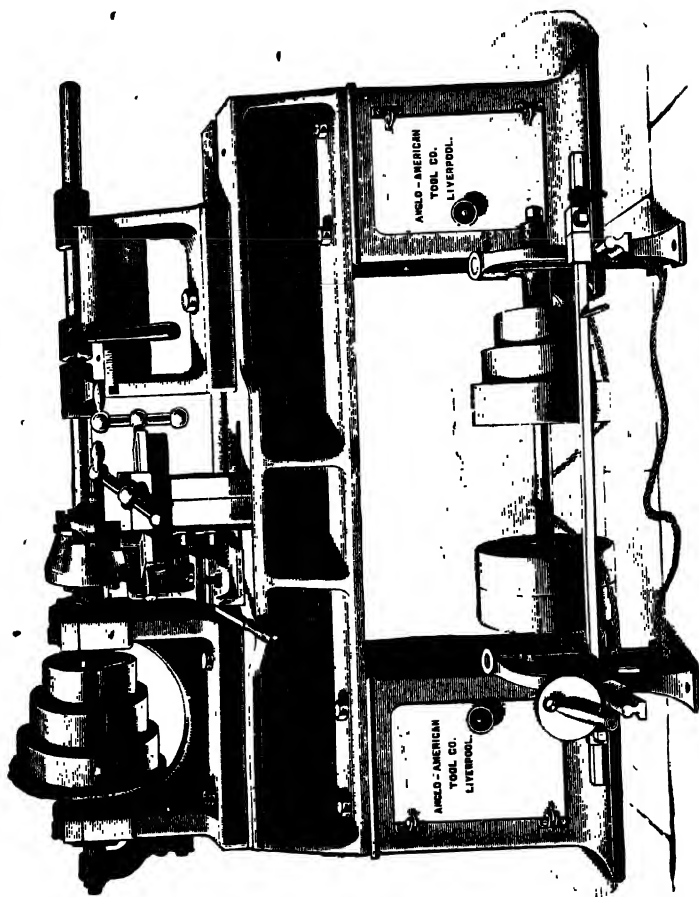
Small Double-Arm Bench Press.



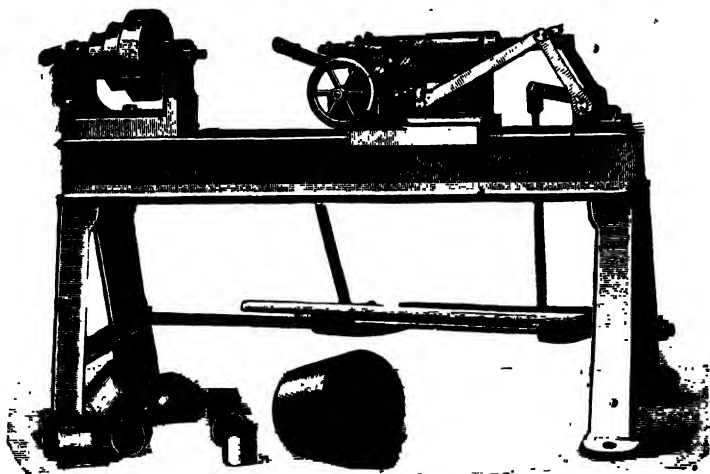
Small Fly Press.



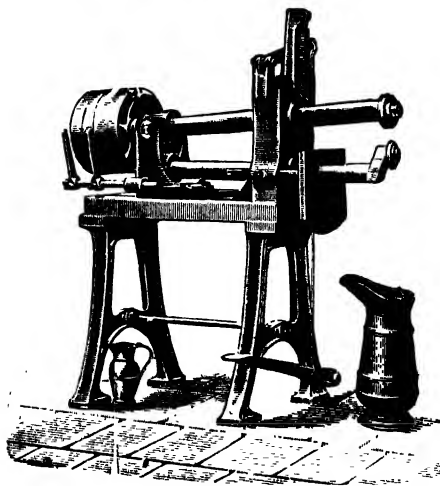
Multiple Punching Press for Sheet Metal.



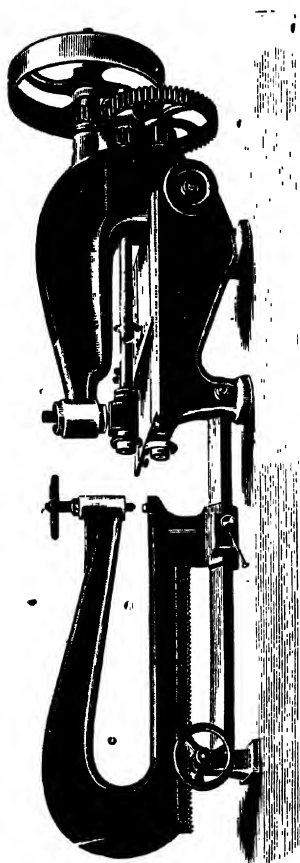
Sheet Metal Spinning Lathe.



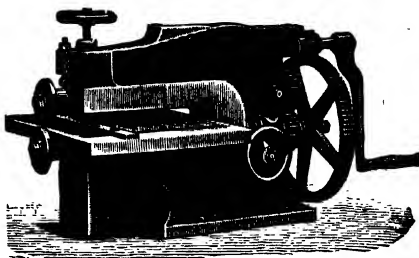
Trimming and Beading Lathe.



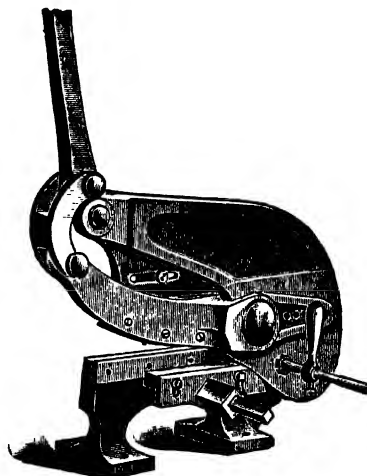
Seaming Machine.



Circle and Strip Shearing Machine.



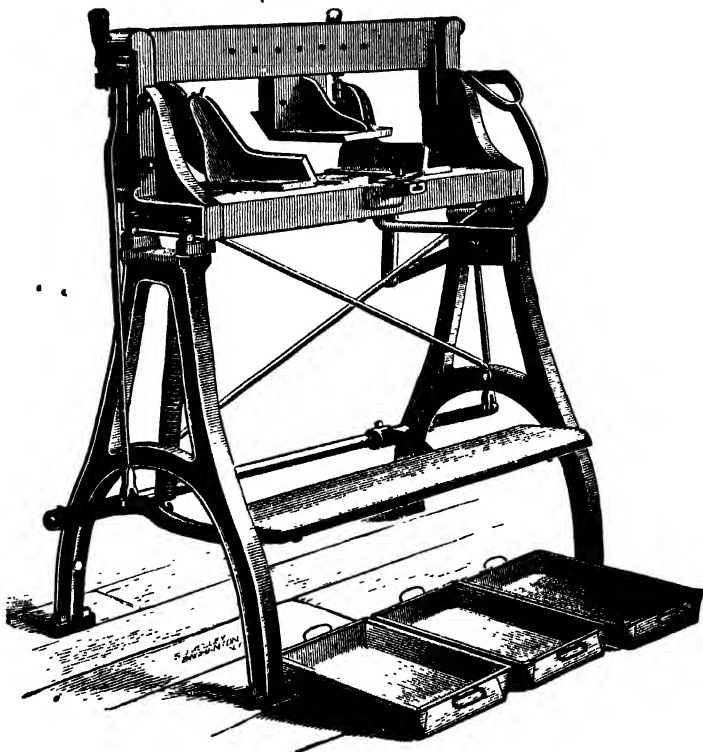
Hand Strip Cutting Machine.



Hand Lever Shears.

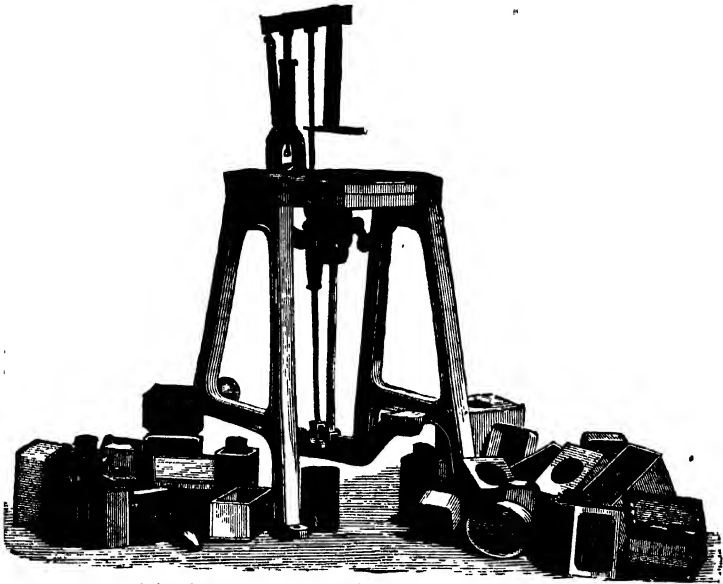


Treadle Guillotine Squaring Shears.

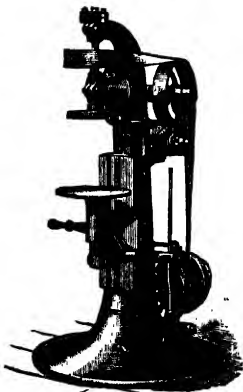


Pan-Forming Machine.

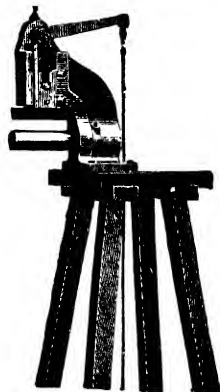




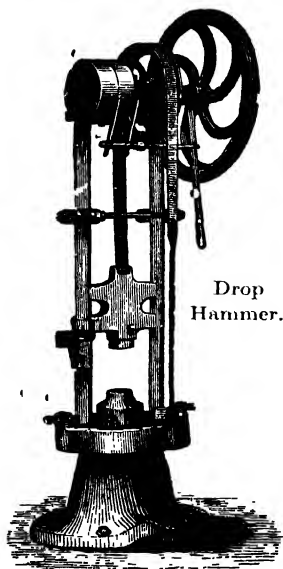
Crimping Machine for Fixing Tops and Bottoms.



Double Seaming Machine for Ends.



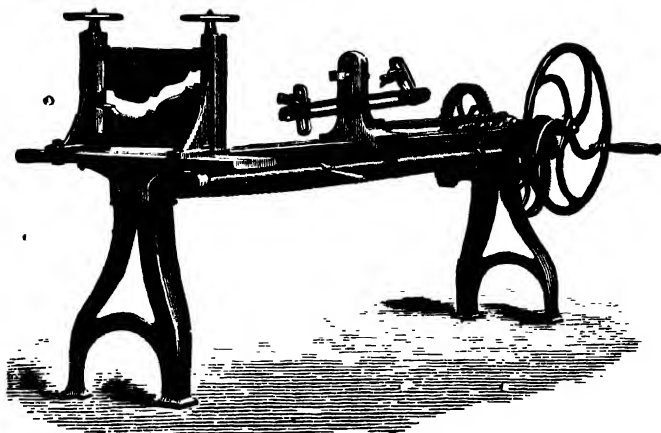
Treadle Grooving Machine.



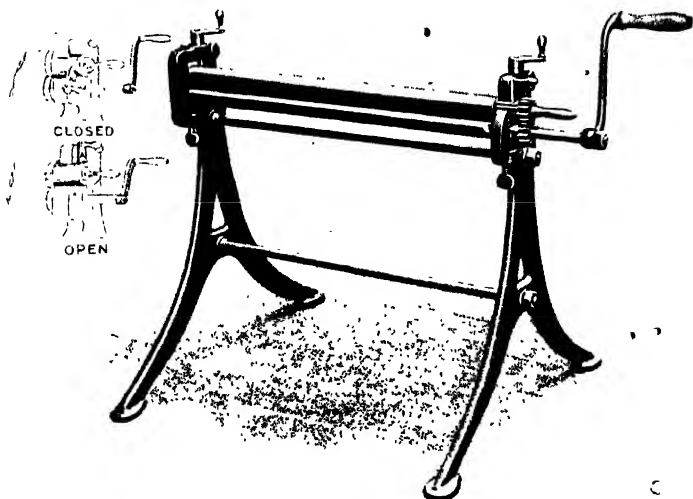
Drop  
Hammer.



Spring Hammer.

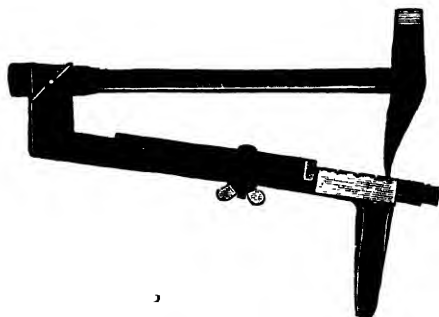


Drawing Machine for Mouldings.

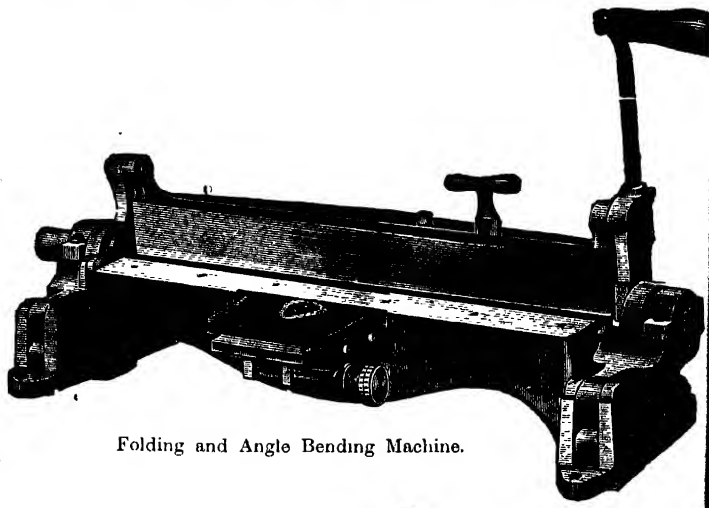


(Rhodes & Sons, Ltd.)

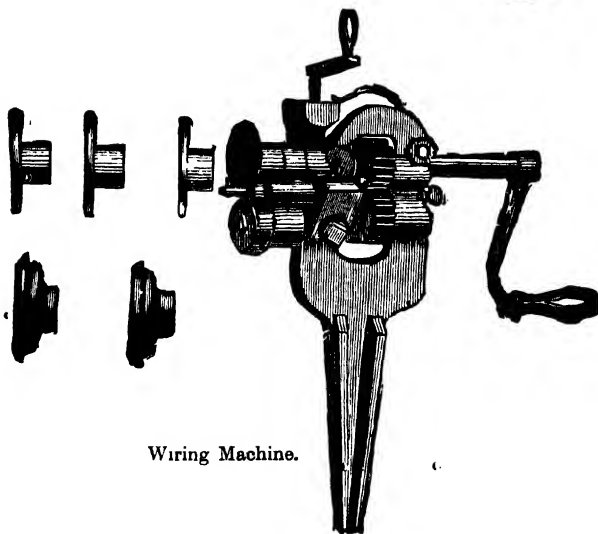
Hand Rolls for Sheet Metal Work.



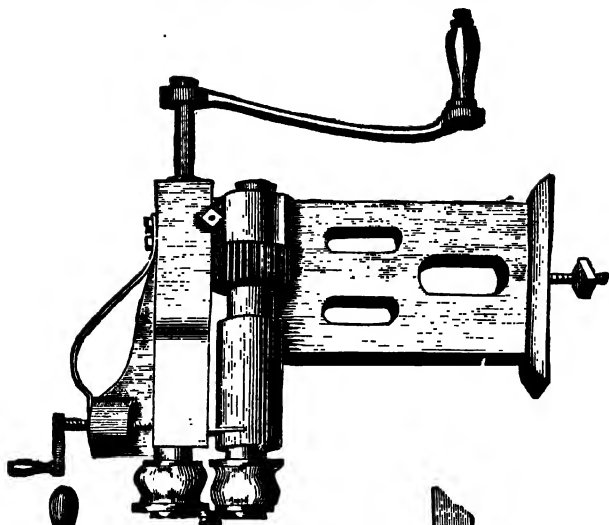
Hand Swage.



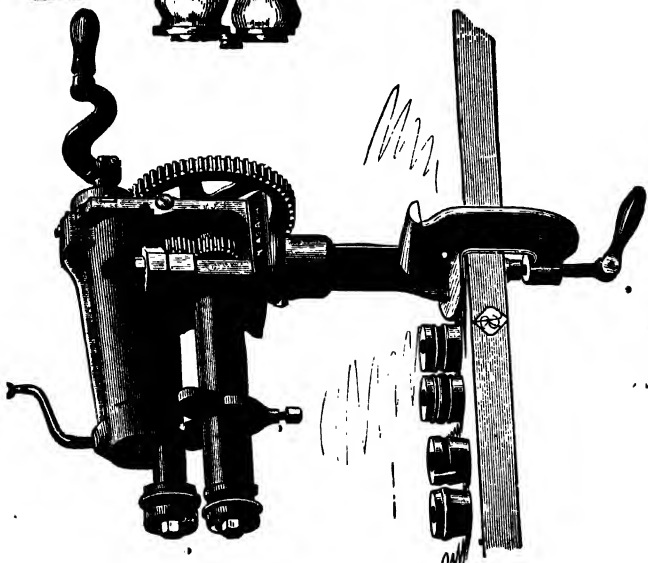
Folding and Angle Bending Machine.



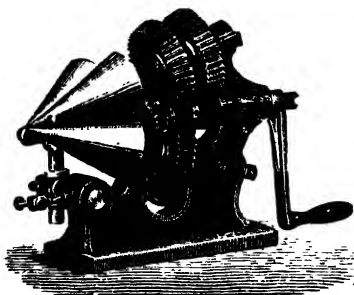
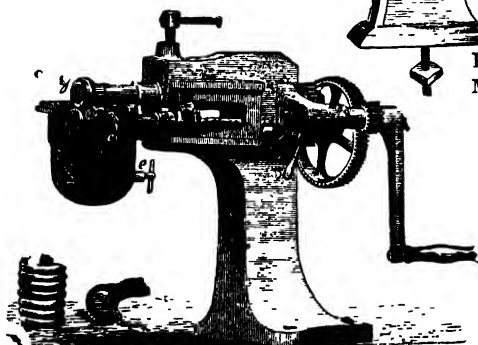
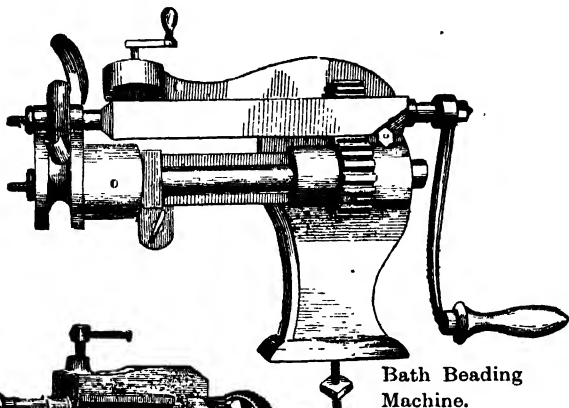
Wiring Machine.

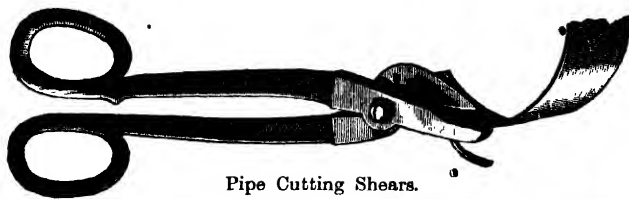


Swaging Machine.

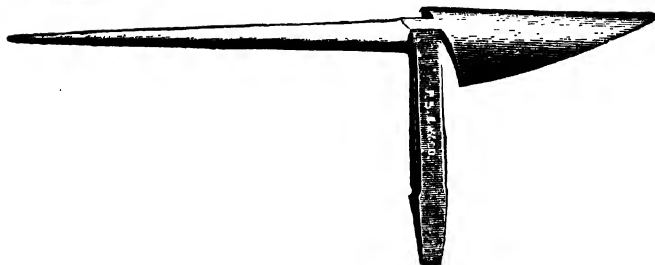


Long Arm Swaging Machine.

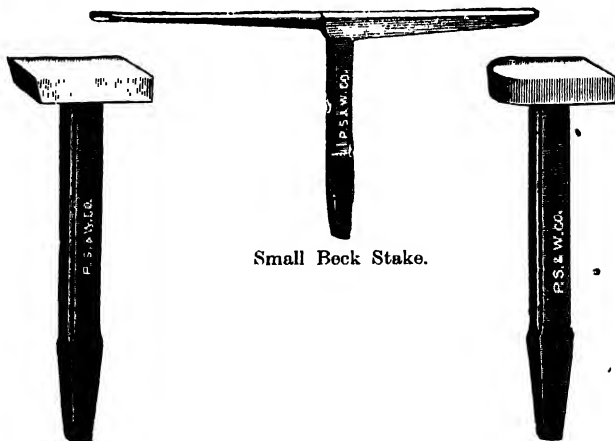




Pipe Cutting Shears.

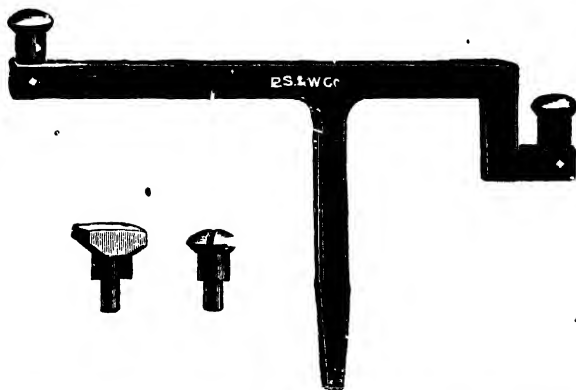


Funnel Stake with Beck.

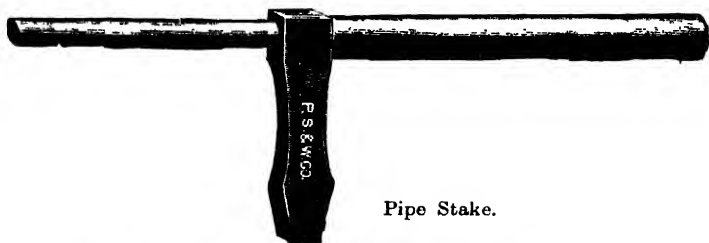


Pan Stake (Square).

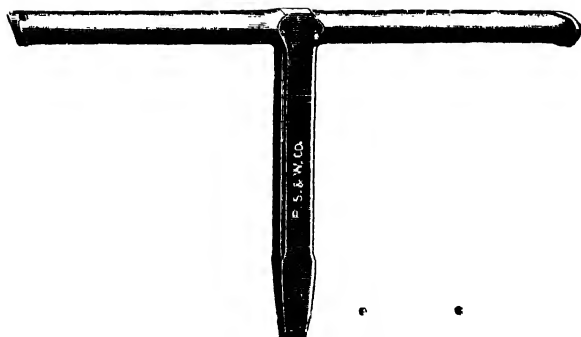
Pan Stake (Round-ended).



Horse and Heads.



Pipe Stake.

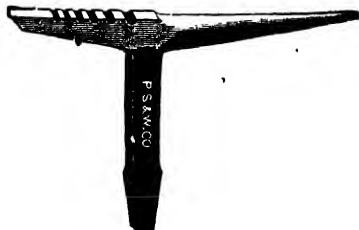


Small Pipe Stake.

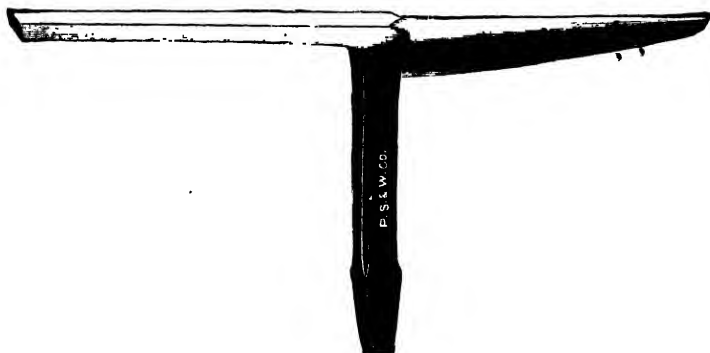




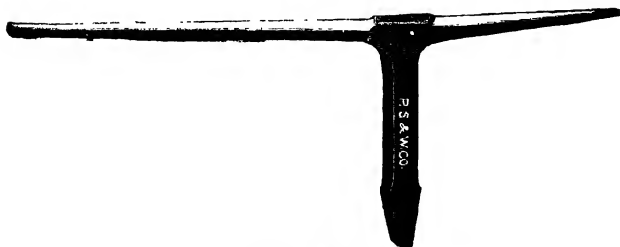
Creasing Iron.



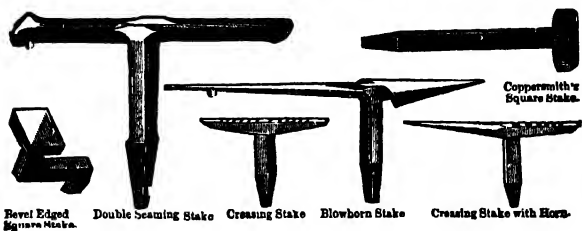
Creasing Stake and Horn.



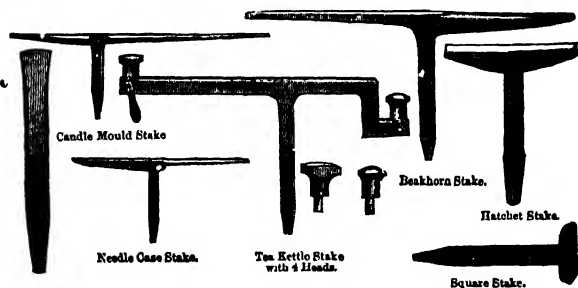
Double-ended Round and Square Side Stake.



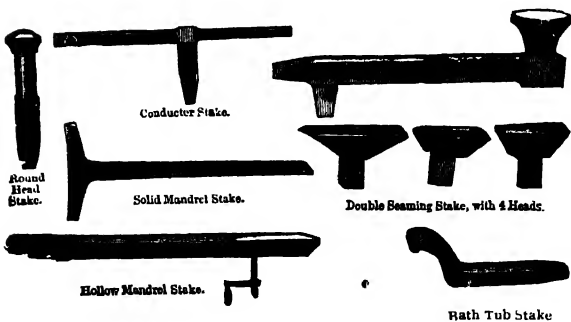
Large Beck-Iron.

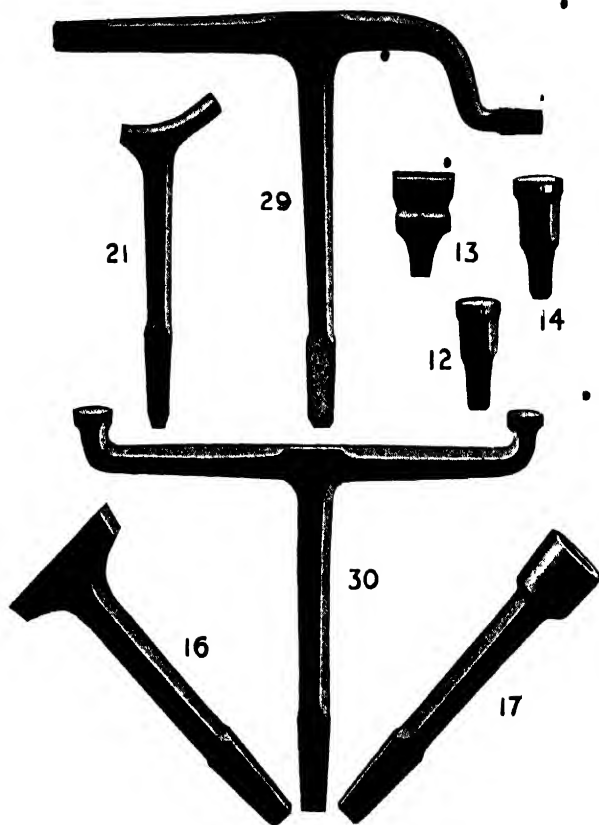


Coppersmith's Square Stake.



Square Stake.





(Rhodes & Sons, Ltd)

No. 21. Teapot Neck Tool.

No. 29. Tinsmith's Horse.

No. 12. Round Head for Horse.

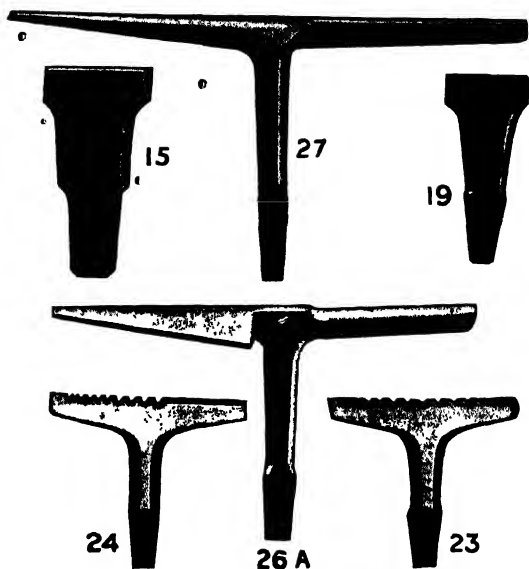
No. 13. Long Head for Horse.

No. 14. Oval Head for Horse.

No. 30. Saucepan Belly Stake.

No. 16. Tea-Kettle Bottom Stake.

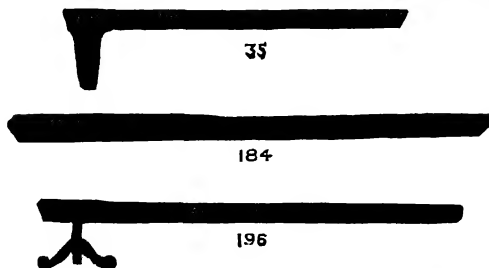
No. 17. Round-Bottom Stake.



(Rhodes & Sons, Ltd.)

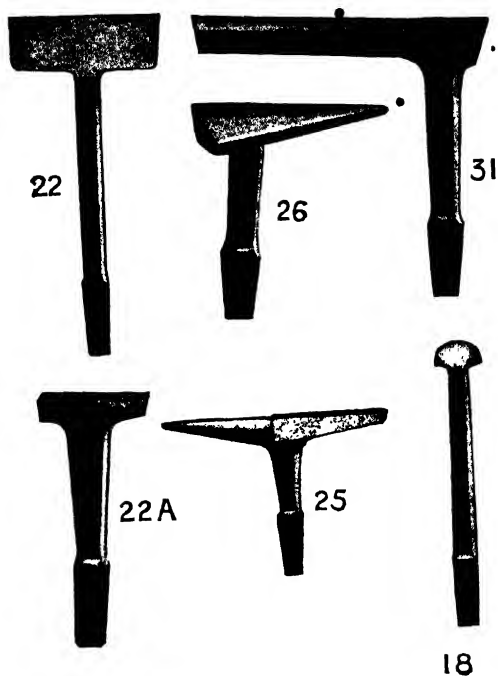
No. 15. Tinsmith's Anvil.  
No. 27. Beck-Iron.  
No. 19. Anvil Stake.

No. 24. Crease Iron.  
No. 26a. Funnel and Side Stake.  
No. 23. Grooving Stake.



(Rhodes & Sons, Ltd.)

No. 35. Pipe Stake. No. 184. Cast Mandril.  
No. 186. Hollow Mandril Stake.



(Rhodes & Sons, Ltd.)

No. 22. Hatchet Stake.

No. 26. Funnel Stake.

No. 31. Side Stake

No. 22a. Drip Pan Stake.

No. 25. Extinguisher Stake.

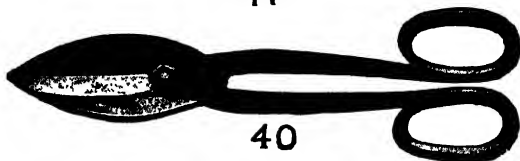
No. 18. Half-moon Stake.



• 42



41



40

No. 42. Straight Snips.

No. 41. Bent Snips.

No. 40. Scotch Shears.

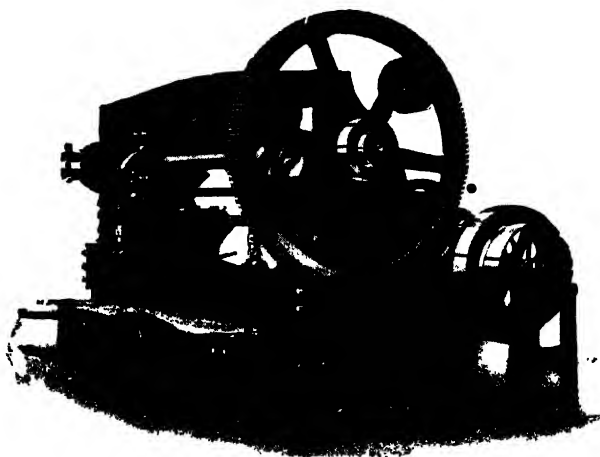


Rhodes' Stock Shears (Right-Handed).



(Rhodes & Sons, Ltd.)

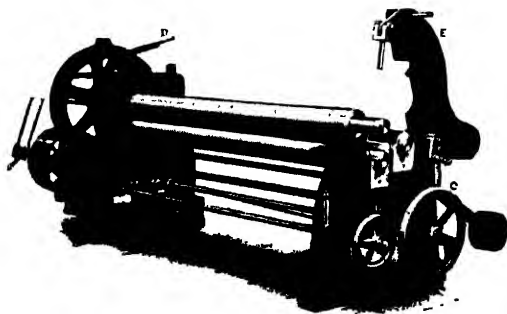
Rhodes' Block Shears (Left-Handed).



*(Rhodes & Sons, Ltd.)*

**High Speed Shears.**

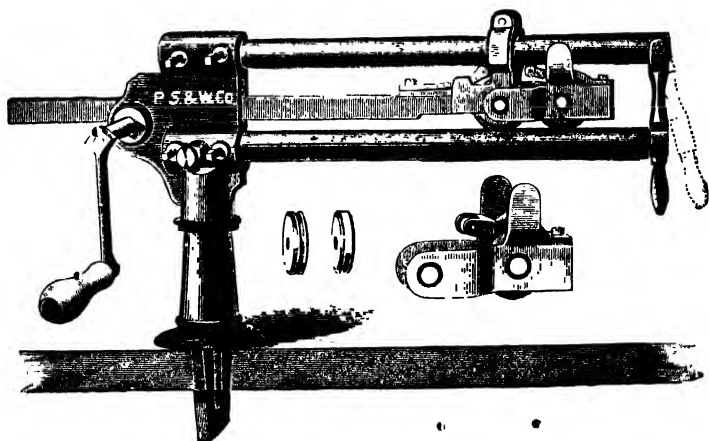
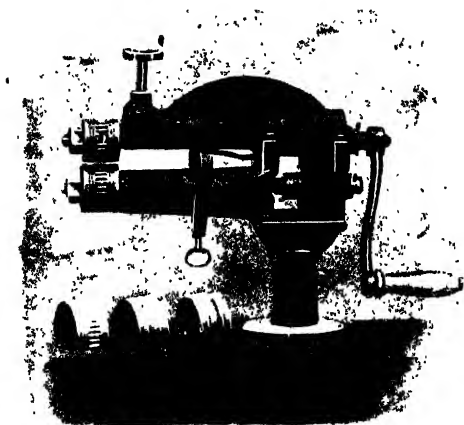
Showing the sheet crushed or flattened on the edge previous to being trimmed.



*(Rhodes & Sons, Ltd.)*

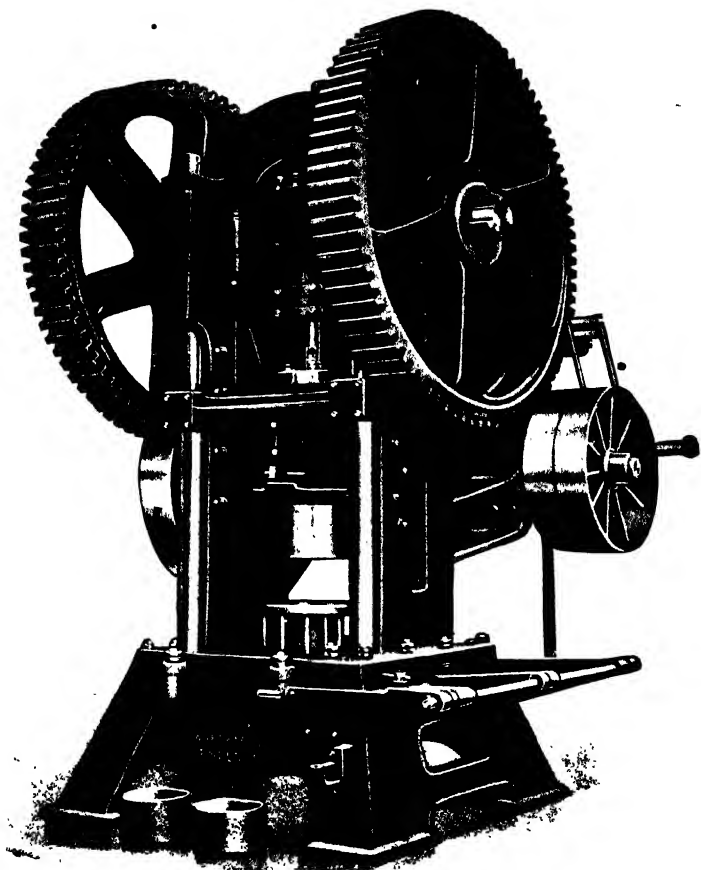
**Power Slip Rollers.**

Showing the end bearing open and the top roller raised for easy withdrawal of tubes.



Combined Grooving and Closing Machine.





*(Rhodes & Sons, Ltd.)*

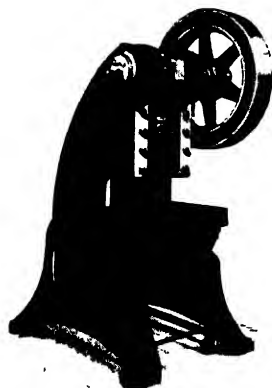
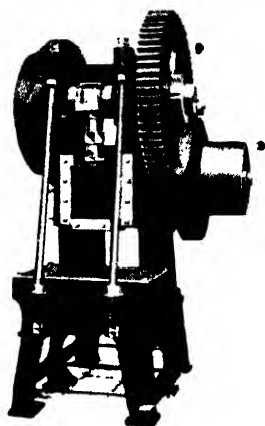
**Double-sided Single Action Deep Drawing Press.**



High Speed Shears.

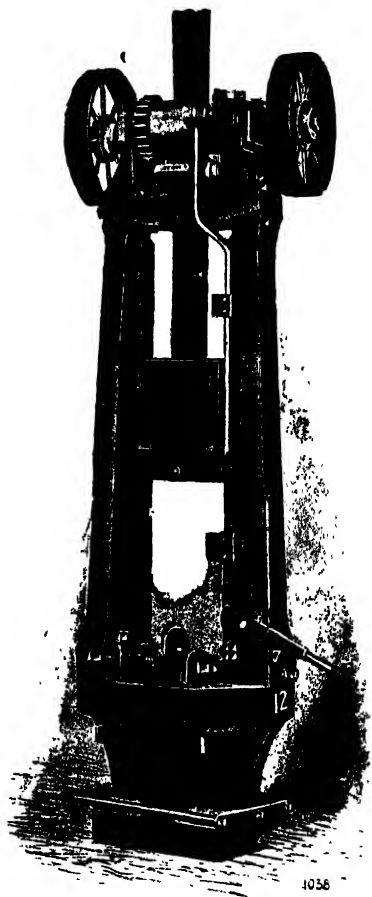
(Rhodes & Sons, Ltd.)

Showing shears for cutting mild steel plates 6 ft. wide by  $\frac{1}{4}$  in. at one stroke.

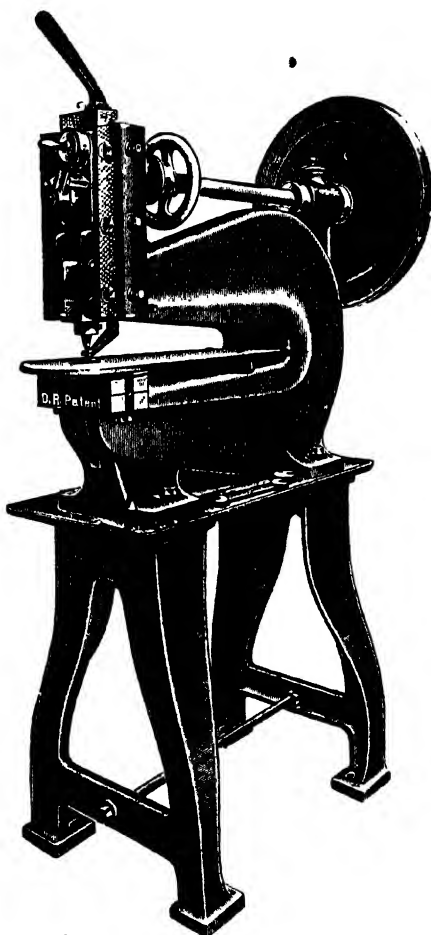


(*Rhodes & Sons, Ltd.*)

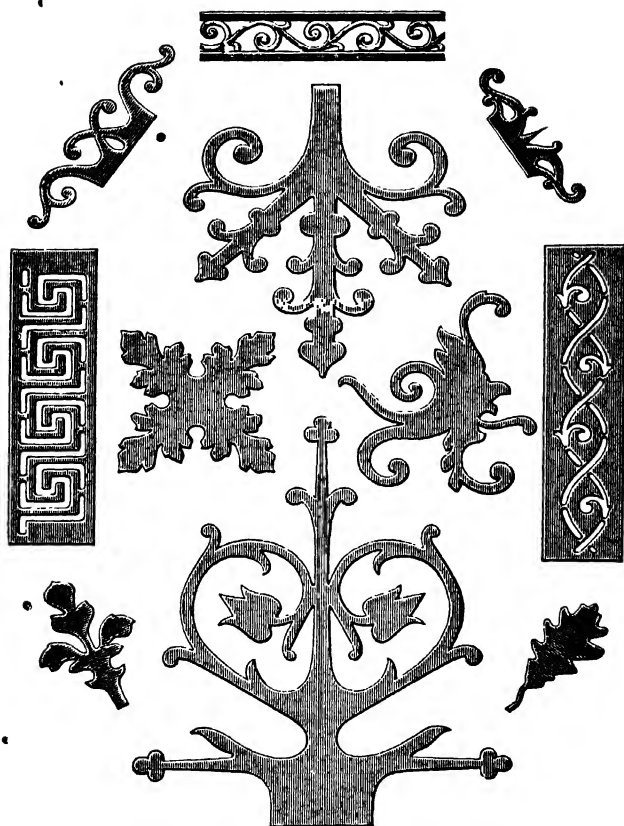
High-grade Inclinator Power Presses.



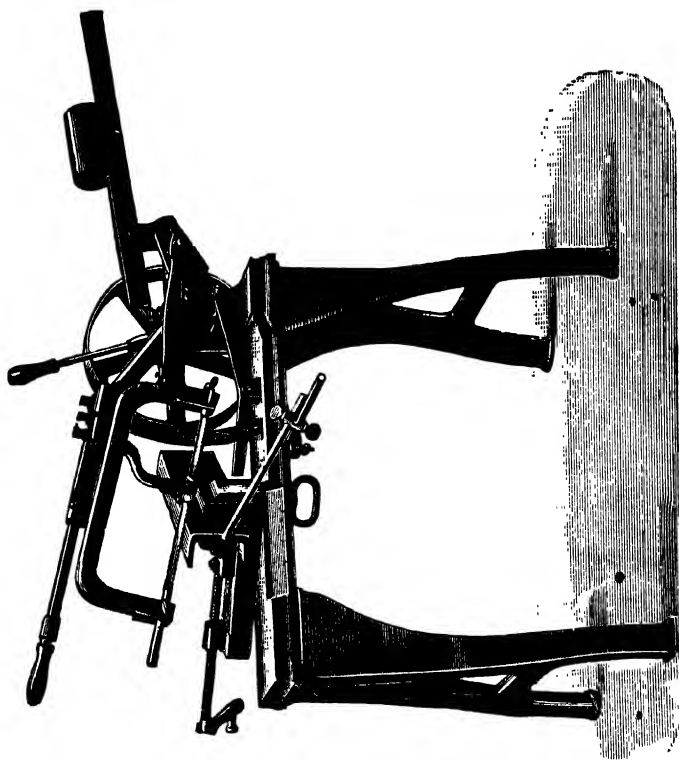
Power Stamping Press.



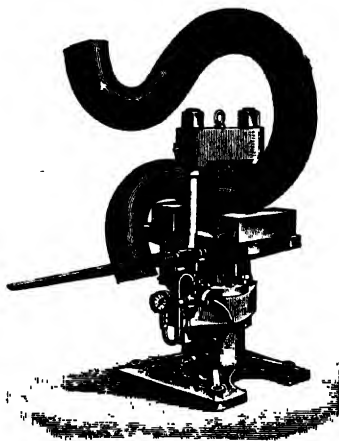
Jig Punching Machine.



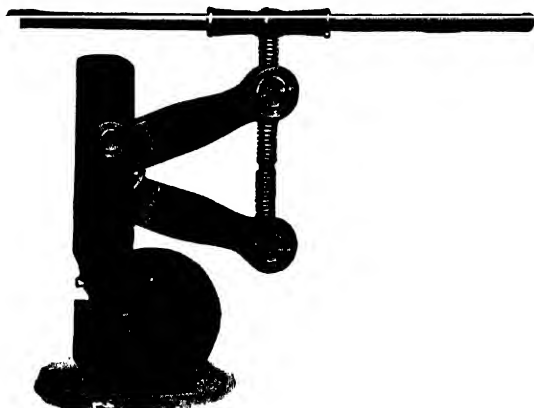
Specimens of Work, Patent Jig Punching Machine.



Power Hack Saw.

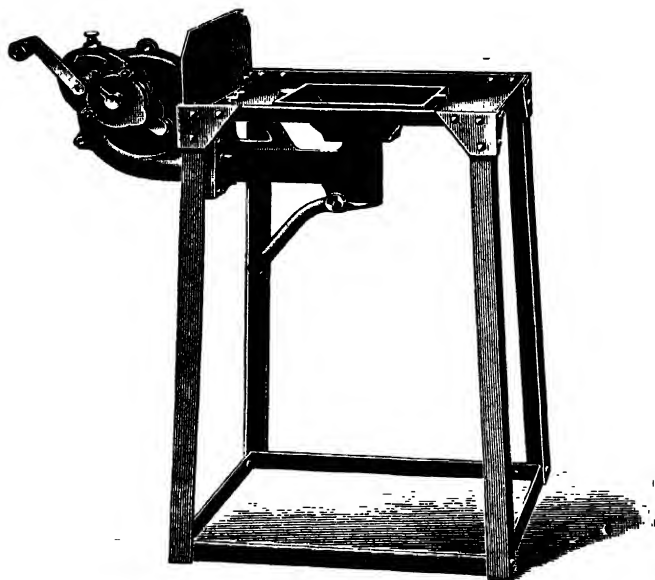


Hydraulic Pipe-Bending Machine.  
For Bending Copper, Iron, and Steel Pipes up to 14 in. diameter.

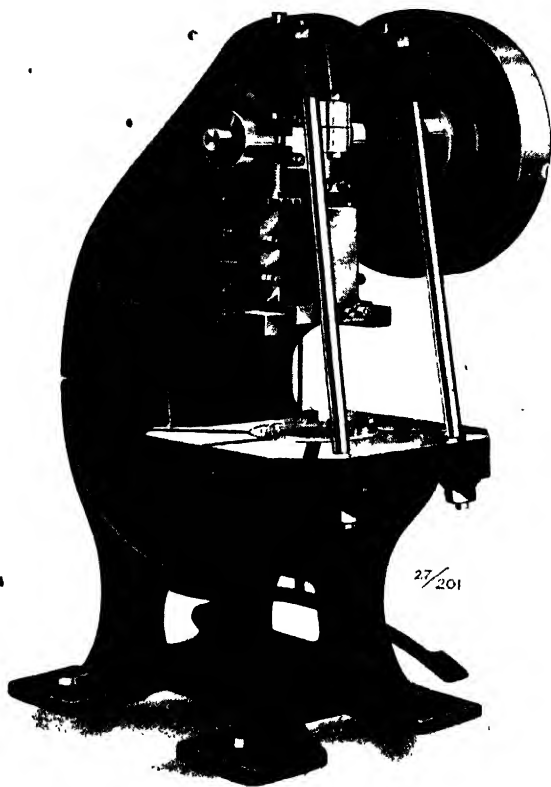


Punching Bear.



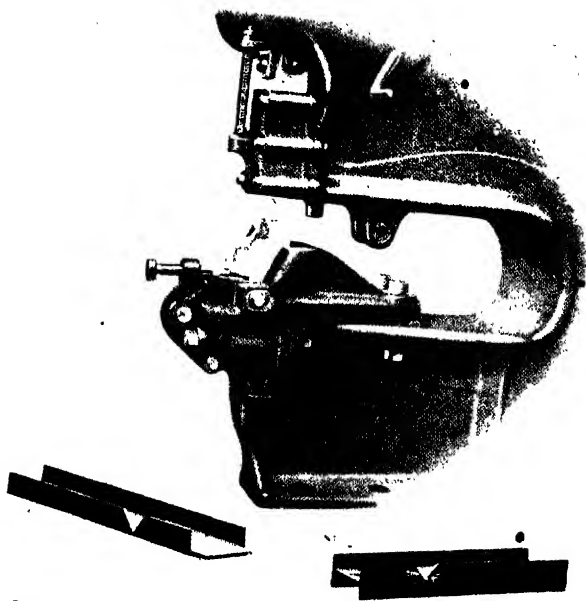


Fan Forge, with Geared Blower for Hand Power



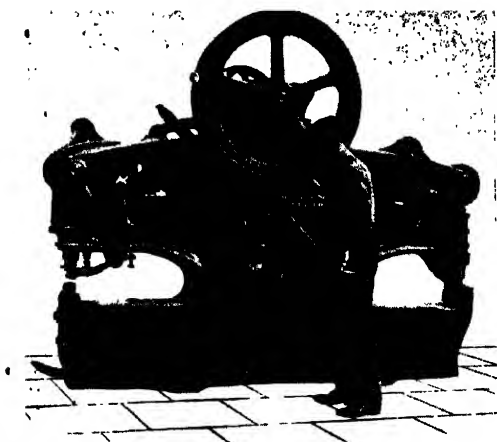
*(Taylor & Challen, Ltd.)*

Power Driven Single Acting Press.



Punching End of a Combined Punching and Shearing Machine.

(James Bennie & Sons, Ltd.)



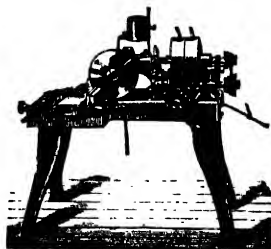
(James Bennett & Sons, Ltd.)

Cutting Tee-Bar at 90° and Punching  
Angle Bar Inside.

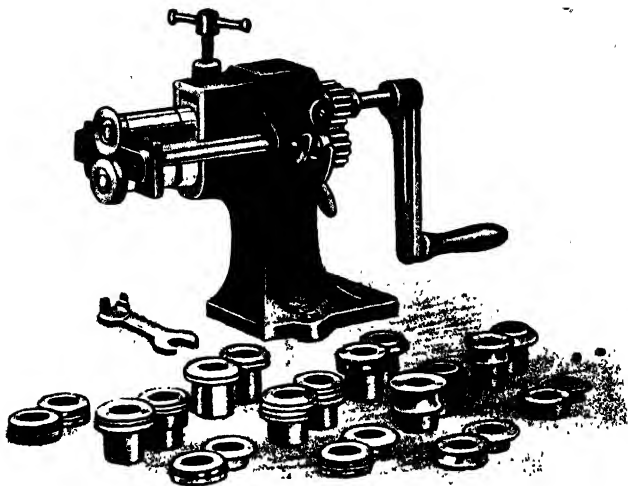


(Melhuish, Ltd.)

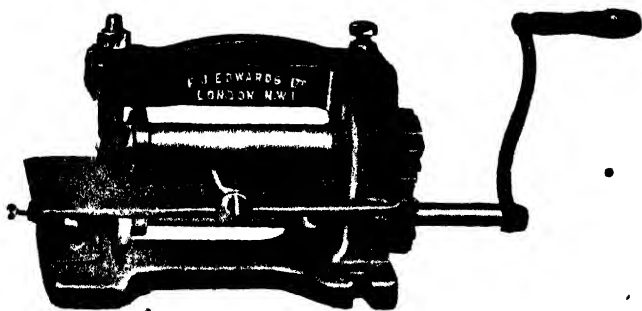
The "Handy" Lever Punching  
and Shearing Machine.



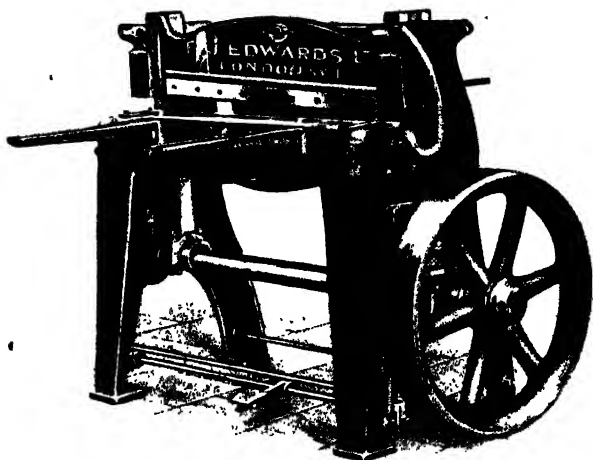
Circular Cold Sawing Machine.



(F. J. Edwards, Ltd.)  
Universal Swaging, Wiring, and Jennying Machine.

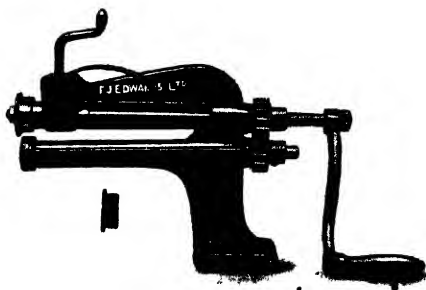


(F. J. Edwards, Ltd.)  
Bench Rotary Shearing Machine.



(F. J. Edwards, Ltd.)

High Speed Shearing Machine.



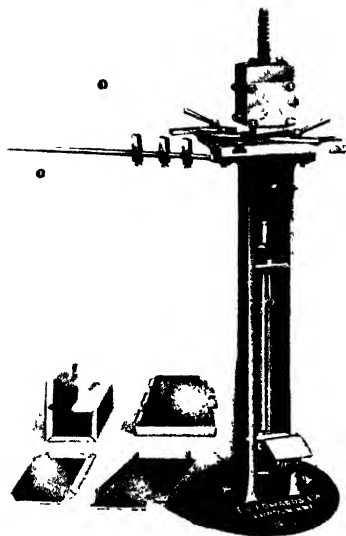
(F. J. Edwards, Ltd.)

Bottom Closing Machine.



*(F. J. Edwards, Ltd.)*

Swing-Beam Universal Cramp Folding Machine.



*(F. J. Edwards, Ltd.)*

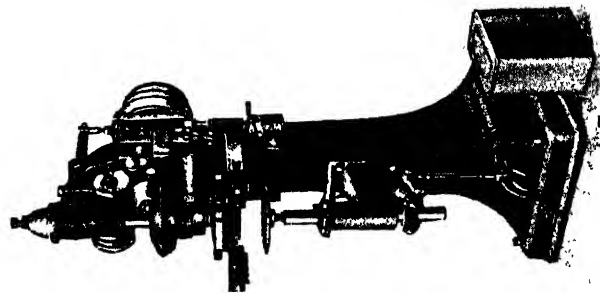
Universal Notching Machine.



*(F. J. Edwards, Ltd.)*

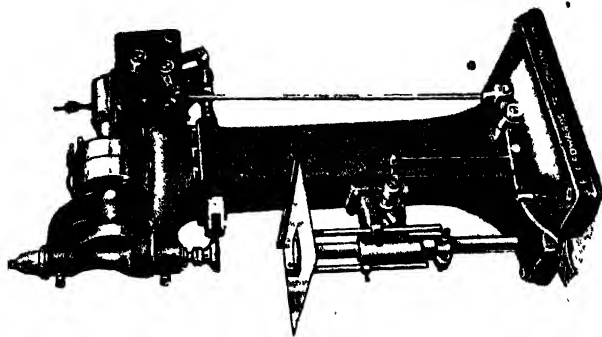
Swing-Beam Hand Lever Angle Bender.





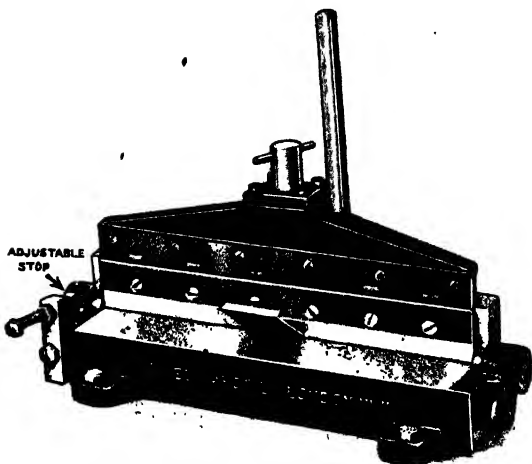
*(F. J. Edwards, Ltd.)*

Double Seaming Machine  
for Irregular Cans..



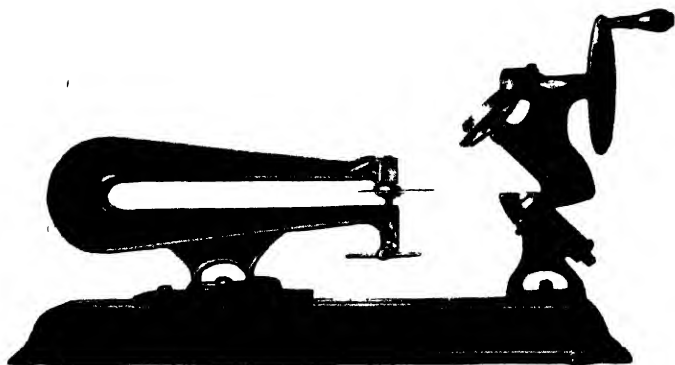
*(F. J. Edwards, Ltd.)*

Double Seaming Machine  
for Round Tins.



(F. J. Edwards, Ltd.)

Flat Bed Narrow Edge Folder.



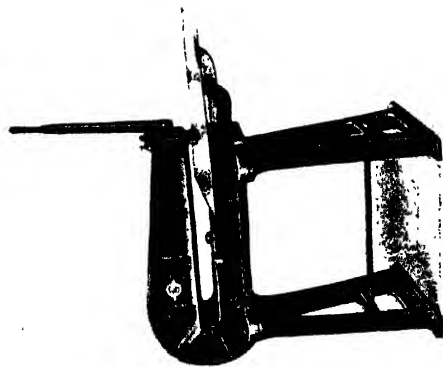
(F. J. Edwards, Ltd.)

Throatless Shearing Machine.

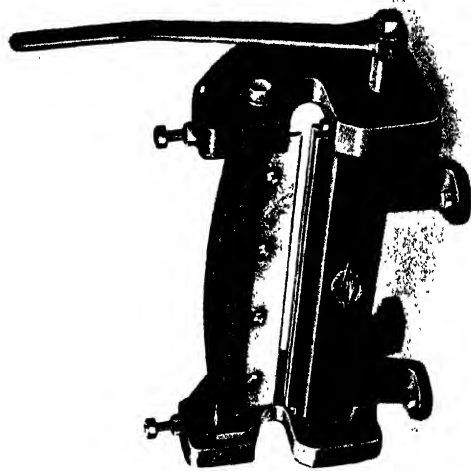


(F. J. Edwards, Ltd.)

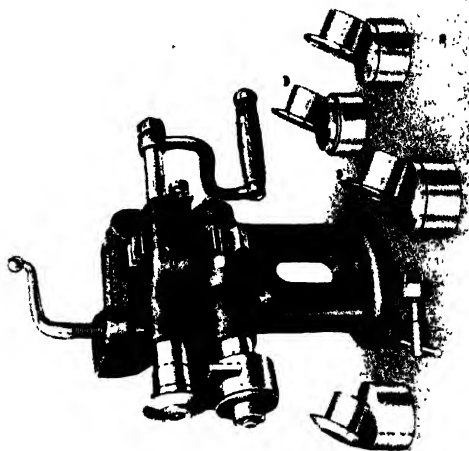
Panel Beating Heads.



(F. J. Edwards, Ltd.)  
Lever Shearing Machine.

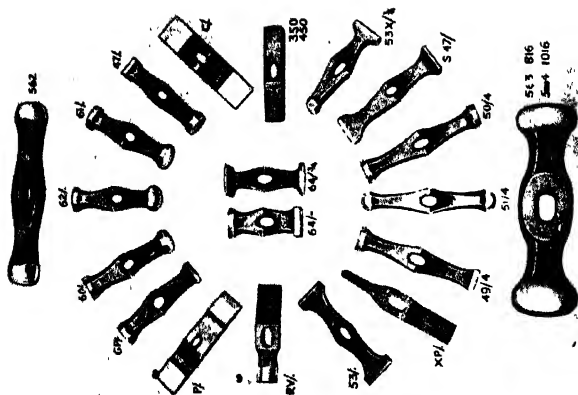


(F. J. Edwards, Ltd.)  
Angle Binding Machine.



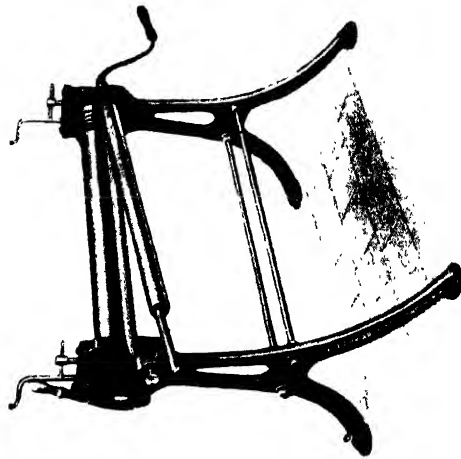
(F. J. Edwards, Ltd.)

## Viring Machine.

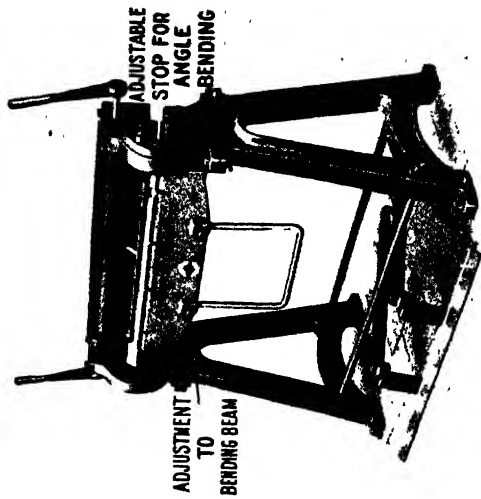


(F. J. Edwards, Ltd.)

Assortment of Hammers for Hollowing,  
• Planishing, Stretching, Creasing, etc.



*(F. J. Edwards, Ltd.)*  
Bending Rolls.



*(F. J. Edwards, Ltd.)*  
Universal Cramp Folding Machine.

# CHAPTER XLIV.

AREA AND WEIGHT OF IRREGULAR SHAPED PLATE, SUCH AS A SHIP'S BULKHEAD.—CONSTRUCTION AND AREA OF PARABOLA.

A VERY convenient method of finding the area of an irregular figure is by the use of what is known as "Simpson's first rule." This briefly stated is as follows: "Divide the figure into any *even* number of strips of equal width; add together the two outside lines or ordinates, four times the even ordinates and twice the odd ordinates; divide this sum by three times the number of strips, the result being the mean width of the figure." When the mean width is obtained the area is of course found by multiplying this into the length of the figure.

The half elevation of a bulkhead is shown in Fig. 354. The depth of this is divided into eight equal parts from the keel up to the deck as shown. The division lines are carefully measured and marked down. To simplify, it is perhaps as well to tabulate results as follows:—

Number of Ordinate.	Length of Half Ordinate.	Simpson's Multiplier.	Products.
	Feet.		
1	4.0	1	4.0
2	11.0	4	44.0
3	16.0	2	32.0
4	19.75	4	79.0
5	22.75	2	45.5
6	25.0	4	100.0
7	25.5	2	51.0
8	25.0	4	100.0
9	24.5	1	24.5
		Total	480.0

So that there shall be no confusion it should be noticed that when a figure is divided into an *even* number of strips there will always be an *odd* number of ordinates. Thus, in Fig. 354, there are eight strips which gives nine ordinates.

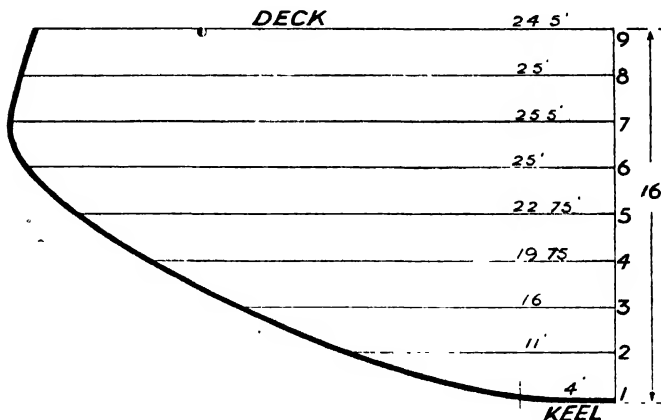


FIG. 354.

Mean half width equals  $\frac{480}{3 \times 8} = 20$  ft.

Therefore area of half figure is :— $20 \times 16 = 320$  sq. ft.

So that area of whole bulkhead =  $320 \times 2 = 640$  sq. ft.

Weight of bulkhead if made of  $\frac{3}{8}$  in. steel plate.

One sq. ft. of  $\frac{3}{8}$  in. plate weighs 15 lb.

Therefore weight of whole bulkhead plate =  $640 \times 15 = 9,600$  lb.

### Construction of a Parabolic Curve.

For special types of gas meters and certain other articles, it is necessary to work up a hollow vessel, parabolic in form, as shown in Fig. 355. For this purpose the parabola must



be first constructed to the required shape of vessel so that a template for measuring and trying purposes can be made to be used in hollowing.

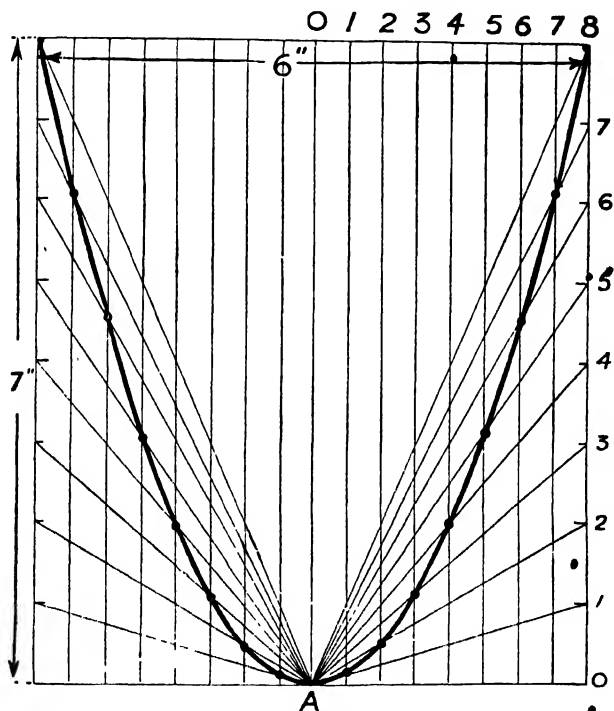


FIG. 355.

The construction of the parabola can be carried out in a very simple manner by the method shown in Fig. 355. The depth 0 A is first set down and then half the diameter 0 8 set across on each side of the centre line. This line is then

either through a poor quality of steel or insufficient annealing. They may show brittleness through incorrect temperature or period of annealing; also lumpiness may appear on the back of the bend due to large grain growth in the steel set up by the two last causes. In the bend tests made on galvanised sheets the spelter may fracture due to bad galvanising or the poor quality of the spelter used.

Where sheets have to be used for hollowing or raising purposes, the simplest test for the sheet metal worker to carry out is that known as "bulging." A ball-faced hammer should be used to sink down a small circular area in the middle of a 3 in. or 4 in. square piece of sheet held over a small hollow in a lead or wooden block. The depth to which the bulge can be carried without fracture is an indication of the quality of the sheet for the purpose required.

In large works, where they have testing laboratories, there is usually no need for the operative to be troubled with the testing of materials, as there are several kinds of machines which indicate the suitability of the material for the purpose for which it is to be used. One of the simplest of these machines is the Erichsen, which cups or humps a piece of sheet and thus indicates its usefulness or otherwise for working-up purposes. Fig. 356 shows a shallow cup on a piece of sheet, whereas Fig. 357 shows a sheet in which the cup has been carried much deeper before fracture takes place.

In many cases the experienced workman can get an idea of the quality of a sheet by simply bending its corner or doubling over the ends to cause a bend across the middle. When sheet metals are welded by the oxy-acetylene blow-pipe, the hand bulge test can very often be applied to specimen weld pieces, or the quality of the weld deposit can be detected by flattening a part of the weld with a ball-faced hammer on an anvil.

**Welding.** All sheet metal workers should learn how to

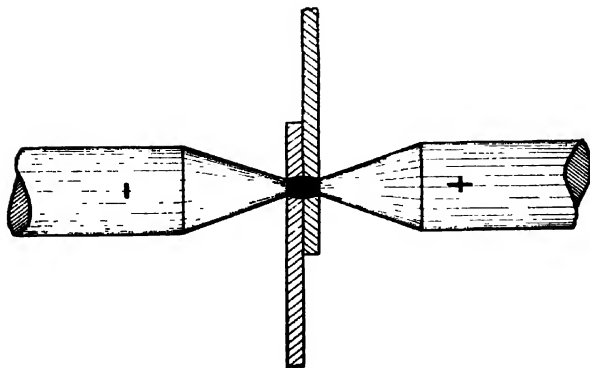


FIG. 358.

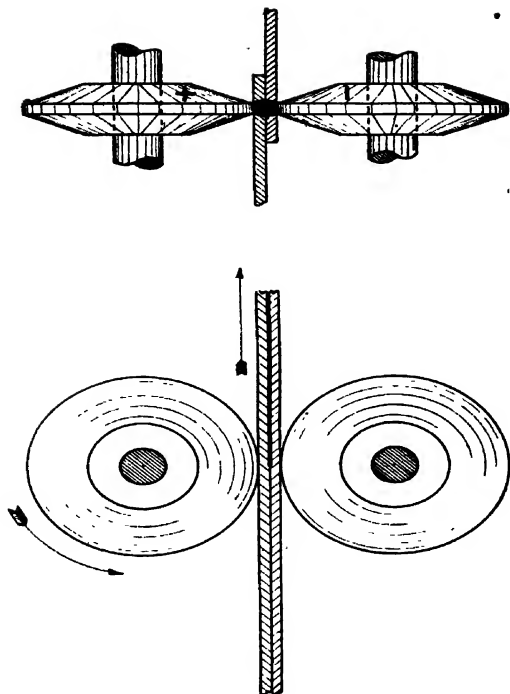
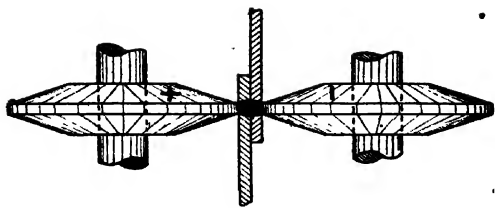


FIG. 359.



carry out simple jobs in brazing, oxy-acetylene welding and spot welding. The various kinds of work which can be carried out by acetylene welding are indicated in Chapter XL, but for a fuller knowledge of the subject the author's book *Electric Arc and Oxy-Acetylene Welding* should be consulted. Spot welding is now very extensively used in place of riveting for sheet and light plate work. The operation is a very simple one; two copper electrodes close down on the joint as shown in Fig. 358, when the electric current passing between the electrodes fuses the two sheets, thus automatically welding them together.

Seam welding is carried out in a similar manner as shown in Fig. 359. Here the electrodes are circular and as the work passes between them the electric current supplies the necessary heat to fuse the sheet. Butt welding is also used to fuse together the ends of hoops, rims, wire, rods, etc.

## CHAPTER XLVI.

## FURTHER PARTICULARS OF METALS AND ALLOYS.

**The Metal Iron.**

IRON exists in great quantities, and is very widely spread over the earth's surface, yet it is very rarely met with in its native state, and even then only in microscopic quantities. It is usually found combined with oxygen, carbon, sulphur, etc., and as iron-ore bears very little resemblance to pure iron, it is not always easy to detect the presence of this element in a substance. Iron-ore may have a great variety of colours, being either white, brown, yellow, red, and almost any shade of these, depending upon its composition. Many of the colours in earthy matter, clay, etc., are due to the presence of iron, in fact, the common red brick owes its colour very largely to the presence of iron oxide.

Some of the best specimens of native iron have been found in connection with meteorites--those strange wanderers in space, which, as shooting stars, we occasionally observe making a dive towards the earth.

The difference between wrought iron and mild steel is very marked, the former due to its method of manufacture being fibrous, whilst the latter is not so. The compositions of the two vary very little, yet there is a considerable difference in their properties, indeed, the term "mild steel" is more or less a misnomer, and it has been proposed that "ingot iron" should be substituted for this, so as to avoid any confusion in the use of the term "steel." In the manufacturing of wrought iron, the pig iron in the furnace is really never brought to a molten state, but is simply puddled in a pasty form for the removal of a fair proportion of its impurities. The puddled ball or bloom is

then removed to be hammered and rolled. In this process further impurities are squeezed out, and those remaining take up the form of slag threads, which are made longer and thinner by rolling and drawing. The structure of a



FIG. 360.

Wrought Iron, Polished and Unetched, to a Magnification of 100 Diameters.

piece of wrought iron bar is shown in Fig. 360, to a magnification of 100 diameters. Here several large slag threads are seen running lengthways of the bar, and there are also numbers of small slag threads; in between these will be observed the portions of more or less pure iron. It should be noticed that these alternate threads or layers of slag and iron give wrought iron its distinctive property of being fibrous.

In the earlier days, up to about two centuries ago, the iron-worker nearly always made his own iron before

proceeding to work it up into either wire or any other shape. This he did fairly simply by mixing iron-ore and charcoal together and heating until he obtained a pasty mass, which he proceeded to hammer out to form a little lump of crude iron, then by continual hammering (hence the name "wrought iron") he gradually improved the quality of the metal. This has given rise to the common idea, which is quite correct, that wrought iron is considerably improved when well hammered at the proper temperaure.

The good quality of Swedish charcoal iron has been extolled for many, many years. This fine quality is due to the great purity of the material, and this is seen in the structure of a charcoal rod, as shown by the microscopical photograph, Fig. 361. It will be noticed that the threads, or patches of slag are very few and very small as compared with the structures shown on Fig. 360. Also in Fig. 361 the beautiful crystal formation will be observed, which is always characteristic of a pure iron. The crystal grains here are rather large, but even these amount to about 12,000 to the square inch. In the specimen shown, the weight of total impurities only amounts to about 3 oz. in 100 lb. of the metal. In spite of all that has been said about charcoal iron, one of its defects is want of uniformity in composition. It may also be mentioned that the qualities of some modern mild steels, or ingot irons, are equal to that of the best kinds of wrought iron.

The great value which is attached to iron is due to the fact of its plentiful supply, there being only one other metal, namely, aluminium, of which there is a greater quantity on the earth's surface. It is easily produced from its ores and consequently can be sold at a comparatively low price. Its chief virtue is in its enormous strength, a bar of wrought iron, one square inch in section, requiring no less a pull than about 20 tons before it can be broken. Roughly, this means that if a bar of iron, one inch square, was used instead of a rope in a tug-of-war, the pulls of about 300 men

on each half of it would be required to break it asunder. By the addition of suitable materials to form steel, together with subsequent treatment, like wiredrawing and rolling, this strength of 20 tons can be increased up to as much as 250 tons. Also, its properties of ductility and

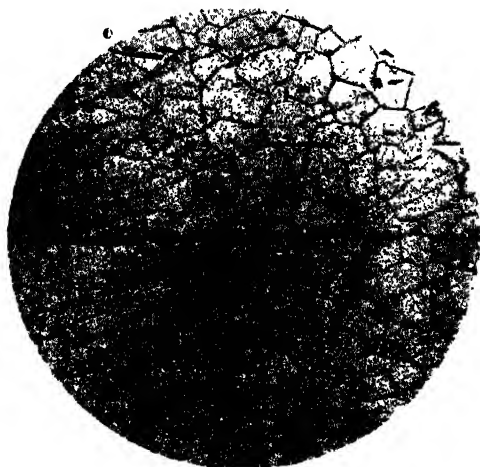


FIG. 361.

Charcoal Iron, Polished and Etched, to a Magnification of 100 Diameters.

malleability are exceedingly valuable, as through these iron can be worked into an infinite variety of shapes and forms.

Whilst iron has all the advantages mentioned above, it has one very serious disadvantage, and that is the readiness with which it corrodes and wastes in a damp atmosphere. However, great strides have been made in the production of rustless steels and other non-corroding alloys, but these are usually too costly except for special purposes.

**Mild Steel or Ingot Iron.** Mild steel differs from wrought



iron both in method of manufacture and composition. It also does not usually have the fibrous nature of wrought iron. In making mild steel the molten metal is generally taken direct from the blast furnace to the open hearth or other type of steel furnace, and after being purified is tapped into large ladles. After certain additions it is then run into ingot moulds. After solidification the ingots are put into a soaking furnace and subsequently rolled down to bars or flats, and then, later, the bars are cut into short lengths and rolled crossways into sheets.

The general composition of the three kinds of iron is as follows—

Analysis.	Wrought Iron.	Charcoal Iron.	Mild Steel.
Carbon percentage	0.01 to 0.05	0.01 to 0.06	0.05 to 0.15
Silicon ..	0.06 .. 0.15	0.01 .. 0.03	0.01 .. 0.12
Sulphur ..	0.25 .. 0.05	0.01 .. 0.03	0.02 .. 0.08
Phosphorus ..	0.10 .. 0.30	0.01 .. 0.02	0.01 .. 0.08
Manganese ..	0.03 .. 0.15	0.05 .. 0.07	0.20 .. 0.40

A photomicrograph of a very low carbon mild steel is shown in Fig. 362. To prepare this a small piece of steel was filed down to give a flat surface about half an inch in diameter, this being subsequently rubbed down with various grades of emery paper and finally polished to produce a brilliant flat surface. After being slightly etched by dipping into a weak solution of picric acid it was photographed. The real size of the small area reproduced in the photos shown is just about the diameter of a hole made in a piece of paper by sticking a small pin through it.

The various kinds of steels can be detected by the use of the microscope. As an illustration, Fig. 363 shows the microstructure of a medium carbon steel and on comparison with Fig. 362 it will be seen what a vast difference there is between the two.

The microscope can also be used to examine the changes brought about by heat treatment. Fig. 364, on the left side, shows the compressed structure of a cold rolled plate, whilst the right-hand side shows the mild steel after being

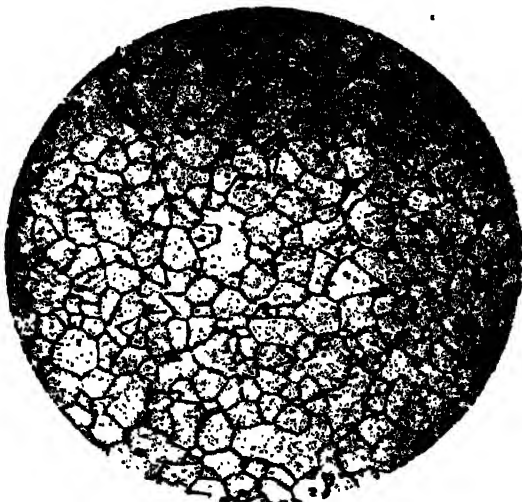


FIG. 362.

Mild Steel, Polished and Etched, to a Magnification of 100 Diameters.

annealed. It will be observed that the grains have reformed, the fibrous appearance being entirely obliterated.

By varied heat treatment all sizes of grains can be obtained, but usually the small-grained sheet is that which is best for toughness as required for severe cold working or deep stamping.

### **The Metal Zinc.**

**Properties.** The pure metal when highly polished has a bluish-white appearance when compared with the

somewhat yellow cast of tin or the white lustre of silver. It is capable of taking a high polish which very soon tarnishes when exposed to the atmosphere if it is not protected by a suitable lacquer. Although it readily

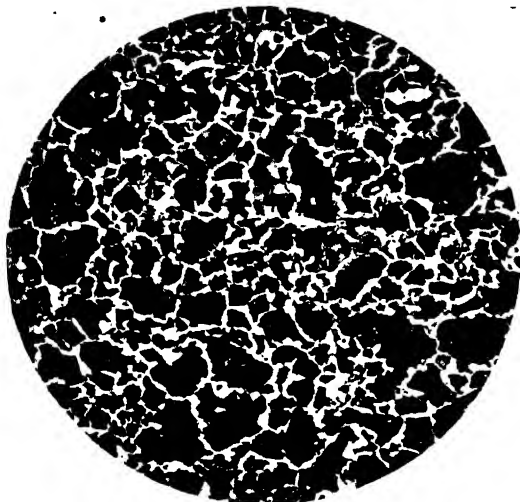


FIG. 363.

0.55 per cent. Carbon Steel, Polished and Etched, to a  
Magnification of 100 Diameters.

corrodes when exposed to an impure or moist air, its very great advantage when compared to iron is that the coat formed on the metal when tarnished or corroded acts almost as a protective varnish, inasmuch as it firmly adheres to the base metal and is not readily dissolved by rain-water, and thus in this respect differs materially from the rust on iron which is quickly washed away under similar conditions. Indeed, it might be said that the real value of zinc (in the form of sheets or as a coating in galvanising) is in a large measure due to the above-mentioned property.

In commerce it is usually spoken of as "spelter," and is somewhat impure, containing as a rule not more than 99 per cent. of zinc. The pure metal is about as soft as copper, but the impurities which the spelter used in industry contains hardens it up considerably.

Whilst the pure metal is malleable and will hold up to a fair amount of hammering and rolling, the ingot zinc is

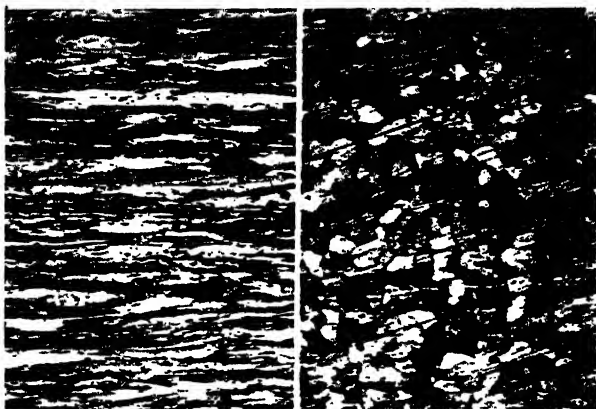


FIG. 364.

Shows Micro-structure of Cold Rolled Mild Steel (on Left)  
and the Micro-structure after Annealing (Right).

somewhat hard and brittle at ordinary temperatures, an ingot being readily broken across under a blow from a heavy hammer. When broken, if the metal of the ingot is free from iron, the fracture exhibits large crystal faces of high metallic lustre. Generally, the more brilliant the faces of the crystals the less is the amount of iron contained in the spelter. When examining the fracture of an ingot the purity should not be judged solely by the largeness of the crystal faces, as these may be large or small according as

the casting temperature was high or low. The cleanness and brilliance of the crystal face is the best indication of the purity of the metal.

Zinc is annealed or softened when heated to a temperature of from 100 to 150° C. for about half an hour, and may then be rolled into sheets and drawn into wire, and in working sheet zinc or wire during the winter time care has to be taken to see that it is warmed up before any attempt is made to bend it. A peculiarity of the metal, however, is that if it is heated to a higher temperature of about 250° C. it becomes so brittle that it can be hammered into a powder.

The strength of the metal is very low: in the cast state it is about  $1\frac{1}{4}$  tons to the square inch, but can be raised from 8 to 10 tons in sheets and wire.

In the ingot form spelter is about seven times the weight of water, but when in the fluid condition as in a galvanising bath, it is just about six and a half times the weight of water, which means to say that a cubic foot of the molten metal will weigh about 405 lb., as against 436 lb. for a cubic foot of the solid metal. Zinc is lighter than iron to the extent of about 8 per cent.

Zinc melts at a temperature of 419° C., but this temperature becomes lower or higher according to the impurities the metal contains. At 950° C. the metal vaporises, burning in air with a bluish-green flame to form the soft white zinc oxide, a substance very much resembling wool, and which in olden times was spoken of as "philosopher's wool" or "flowers of zinc."

The conducting power of zinc for electricity and heat is fairly good, being about 25 per cent. of that of silver. In this property it is inferior both to copper and aluminium, but superior to tin, iron and lead.

For a given rise in temperature zinc expands to a greater extent than any of the ordinary metals. When compared to iron, for the same rise in temperature it expands more

than twice as much. For instance, a piece of zinc wire when heated from 0° C. to 100° C. will expand 1/344th of its length, whereas an iron wire for the same rise in temperature will only expand 1/770th of its length.

Ordinary commercial zinc is readily attacked by both sulphuric and hydrochloric acid, but the pure metal itself is only slowly acted upon by these acids.

One of the most important properties of zinc is the remarkable power which it has of dissolving iron when the latter is allowed to remain in contact with the molten zinc. Zinc has great affinity for iron, and whilst it is said to form several compounds with this metal it is very questionable whether there really is more than one actual alloy of iron and zinc, the latter metal most likely combining with about 11 per cent. of iron. This property is the real basis of the galvanising process.

**Impurities in Zinc.** Ingot zinc is not the simple metal it is generally thought to be, as usually it contains impurities up to 2 per cent. or more, these being either all or some of the following: lead, iron, cadmium, tin, copper, carbon, silicon, arsenic, antimony, sulphur, silver and small quantities of the more uncommon metals. In addition re-melted spelter may contain aluminium or other metals.

Several photomicrographs, all to a magnification of 100 diameters, have been prepared to show the form of the impurities in spelter and dross. Of the impurities contained in spelter, lead, in the form of small globules, usually accounts for the highest percentage. Lead and zinc have practically no affinity or liking for each other, and when they exist together in the molten condition the lead separates out from the zinc, like water does from oil, and sinks to the bottom of the vessel or pot. But when in a finely divided state it takes a considerable time for these small globules to make their way down through the molten zinc. It is generally thought that small amounts of lead tend to make zinc malleable, but experience shows that when the

proportion of lead exceeds  $1\frac{1}{2}$  per cent. the zinc becomes somewhat weak.

Iron in zinc usually exists in the form of small crystals of the previously mentioned iron-zinc alloy; these are

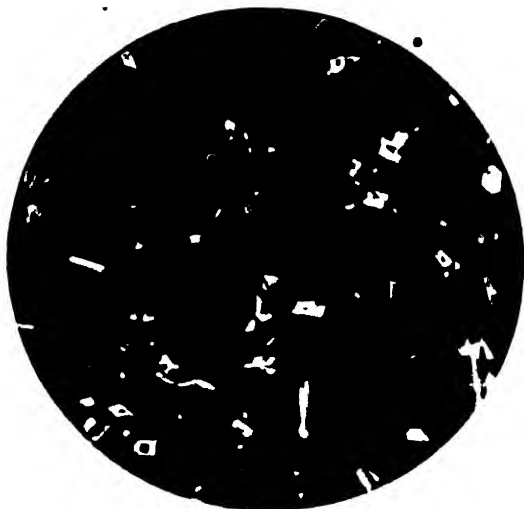


FIG. 365.

Photomicrograph of Spelter to a Magnification of 100 Diameters.

shown by the white areas in Fig 365, zinc of this description containing 0.176 per cent. of iron. When more iron is present these small crystals tend to join together to form larger crystals. When still more iron is present in the zinc it then begins to approximate in composition to a dross. The process of the iron-zinc alloy crystal formation is further illustrated by Fig. 366, this being a photograph which shows the micro-structure of a dross containing about  $4\frac{1}{2}$  per cent. of iron. It will be noticed that the small

crystals have almost disappeared, these joining together to form the larger crystals. It should be mentioned that the black area in between the crystals is pure zinc, so that if the dross from the galvanising pot could be perfectly



FIG. 366.

Photomicrograph of Spelter containing 4.5 per cent. Iron  
to a Magnification of 100 Diameters.

drained it should contain somewhere about 10 per cent. or 11 per cent. of iron instead of 4 per cent. or 5 per cent. as usually obtains, and in this case the black areas would almost disappear. From this it will be seen that a very careful sweating out of the pure zinc form in between the crystals is always desirable from the point of view of economy, as in a 5 per cent. iron dross there is about 40 per cent. free zinc.

Before finishing with iron it should be stated that any



iron in spelter is a disadvantage, as it tends to make the metal brittle and also goes towards the formation of dross in a galvanising bath.

**Composition of Spelters.** The compositions of spelters vary considerably, the following being a few analyses—

Zinc. Per cent.	Lead. Per cent.	Iron. Per cent.	Cadmium. Per cent.	Tin. Per cent.	Copper. Per cent.
98.642	1.205	0.06	0.089	—	0.004
99.05	0.66	0.26	—	0.03	—
97.89	2.00	0.04	0.07	—	—
99.718	0.135	0.20	0.123	—	trace
99.989	—	0.011	—	—	—
99.606	0.36	0.034	—	—	—
99.585	1.16	0.085	—	0.12	0.05
97.934	2.0	0.066	—	—	—

Remelted spelters sometimes have an inferior composition, the following analyses showing this—

Zinc. Per cent.	Lead. Per cent.	Iron. Per cent.	Cad- mium. Per cent.	Tin. Per cent.	Copper. Per cent.	Alumin- ium. Per cent.
96.447	2.05	0.03	0.003	1.41	0.06	—
96.85	0.81	—	—	trace	0.72	1.62
97.00	0.82	0.04	—	trace	0.32	1.82

It will be seen that the last two are high both in copper and aluminium, the effect of these two metals on the zinc structure being most marked.

The impurities in spelter, it may be said, very materially effect the galvanising properties of the metal, and may, indeed, as in the case of that which contained aluminium and copper, make it useless for galvanising purposes.

In the sheet trade a good deal of importance is attached

to producing large and beautiful spangles on the surface of the galvanised sheet (Fig. 367) and all kinds of methods are tried to bring this about. There are many factors which govern the quality of galvanising, such as—

- (1) The kind of surface produced on the sheet in rolling;
- (2) The method and time of annealing;
- (3) The method and time of acid pickling;
- (4) The temperature of the galvanising bath;
- (5) The time the sheet is in the bath;
- (6) The kind of metallic additions to the bath; and
- (7) The treatment of the sheet as it comes from the bath.

It might also be mentioned that the kind and type of fluxing plays a not unimportant part in the production of a clean and bright surface on the sheet.

### **The Metal Aluminium.**

Aluminium is found in nature as one or other of its important compounds in corundum, emery, alundum, and in many precious stones, such as the ruby, sapphire, topaz, and it is also found in the various clays. Indeed, it has been said that the aluminium contained in an ordinary brick is sufficient to coat its surface over about one-eighth of an inch in thickness.

Its chief ores are bauxite and cryolite, the former being oxide of aluminium, together with some iron oxide and silicon; the latter being a compound of aluminium and sodium fluoride. Under present methods of manufacture aluminium is obtained with a purity of from 99 to 99½ per cent., its chief impurities being silicon and iron.

**Physical and Chemical Properties.** It has a specific gravity or relative weight as compared to water of 2·7, this, when compared with 7·8 for iron, shows that it is about one-third the weight of iron when equal volumes are taken. Its melting point is 657° C. It has a tensile strength in the cast state of about 7 tons per sq. in., which may be increased up to as much as 15 tons when the metal is rolled into a

sheet, and when drawn down into fine wire its strength can be increased up to about 29 tons per sq. in.

Aluminium is about half the strength of iron, but as its weight is one-third, it will be seen that a bar of aluminium



FIG. 367.

Photograph of Spangles (Natural Size) on Galvanised Sheet.

of the same length and weight as a bar of iron will be about 25 per cent. stronger.

It is a very malleable metal, and can not only be rolled down into very thin sheets, but metal foil can be produced of about  $1/40,000$  of an inch in thickness. It is an extremely good conductor of heat and electricity, and has the distinction of absorbing more heat to raise it to a given

temperature than most of the ordinary metals. It has a great affinity for oxygen, which is one of the reasons for the difficulty found in either soldering or welding the metal. But it can be welded with the oxygen-acetylene blow-pipe if proper care is taken and a suitable flux used.

When exposed to a dry atmosphere the polished metal keeps fairly bright, but when in contact with a damp atmosphere it corrodes rather rapidly, which causes the metal to become somewhat brittle. It is also affected by being coated with any form of lead paint. It resists the action of most of the acids, but is readily dissolved in warm hydrochloric acid.

It is dissolved by alkalis, and this is usually one of the reasons for the metal wearing away so quickly when vessels used for domestic purposes are cleaned with soda or dry soaps.

On account of its great affinity for oxygen it is sometimes used as a de-oxidiser in the manufacture of steel, but in this respect it should only be used with the greatest caution, as whilst it removes one defect it may set up several others.

The metal in the form of a very finely divided powder is also used in what is known as the "thermit" method of welding, in which iron oxide is rapidly reduced by the aluminium combining with the oxygen, the resulting molten iron being cast or run around any form of iron or steel bar or rail joint which it is required to weld.

**Domestic and Other Uses of the Metal.** Vessels for domestic use made of aluminium are now becoming quite common, and there is no reason why they should not be used for all kind of purposes if care is exercised. First of all, the melting point being low as compared to iron, care should be taken that vessels are not allowed to become "dry" on a hot fire, as the result might be a hole in the vessel. The chief enemy of the aluminium pan is alkali, particularly when in the form of carbonate of soda, even a weak solution of this chemical dissolving the aluminium.

As the metal can be kept quite clean without soda, there is no reason for its use.

As with iron, the small quantity of aluminium salts which may be dissolved in cooking vegetables, etc., will have no deleterious effect on the human system.

In using aluminium vessels for domestic purposes, soups, jams, or other liquids should not be left to stand in the vessel after the cooking operation is finished, and this applies equally to other metal pans or vessels.

**Use in Engineering Industries.** Aluminium is coming into use in enormous quantities in connection with overhead conductors in electric power schemes, as it is found to be an extremely good substitute for copper. It is also being used very extensively in connection with electric cables.

In chemical and other industries aluminium is finding a large use for vats, pans, storage tanks, etc. It is also being used quite a good deal for light castings for motor car and similar purposes.

In the finely powdered form aluminium seems to have in front of it a future for blasting purposes, as when mixed with other compounds it makes one of the most intense and effective of explosives which can be used in connection with mining operations. Also in the powdered form it is used as a filler for the "silver" paint commonly seen.

It is not yet much used as a protective coating for other metals, but as an oxidised alloy with iron it forms the coating on iron articles which are "calorised" to withstand scaling under heat conditions.

**Aluminium Alloys.** Tests show that aluminium when mixed with several other metals, such as copper, magnesium, nickel, zinc, etc., forms extremely valuable compounds. One of these, known as "duralumin," which has a tensile strength of about 30 tons per sq. in., has been used very successfully in connection with airships, aeroplanes, etc.

**Aluminium can be soldered** if the edges of the sheet are first coated with pure tin, and this can be done by heating the edge with a bunsen burner at the same time rubbing with a steel tool and allowing the stick of tin to melt and run down. The edges can then be sweated with either pure tin or ordinary solder. A solder containing 81 per cent. tin and 19 per cent. zinc has been used, but the joint it gives is not stable and comes apart after some weeks.

### **The Metal Tin.**

**Properties.** Tin is a white metal slightly more yellow in cast than the white lustre of silver. It is soft and malleable, and when pure can be hammered to thin foil or leaf. Though flexible it is not elastic, and when in bar form and bent it emits a characteristic crackling sound or "cry," as it is called, due to the internal rubbing of the crystals. The purer the tin the more distinct is the "cry." By repeated bendings of a bar of this metal in the hands its temperature can be considerably raised.

Tin has a specific gravity of 7.3, but commercial tin on account of its impurities is slightly heavier; thus the metal is about seven and one-third times as heavy as water, or a little lighter than iron. It melts at 230° C. At 100° C. it is in the most malleable condition, but at 200° C. it becomes so brittle that it can be pulverised. When melted it rapidly covers with tin oxide, hence to use it economically molten tin should not be allowed to be exposed to the atmosphere. At a temperature below 18° C. tin is liable to change its character entirely and to pass into the form known as "grey tin." It then becomes much lighter, having a density in this condition of only 5.8. The change is accompanied by disintegration and expansion of the metal. At ordinary temperatures the change as a rule is very slow, but the writer has seen the metal alter during the course of a few hours under certain conditions of the atmosphere. The phenomenon is sometimes called the "tin plague" or

"tin disease" or "tin pest," and the strange thing is that it passes from one piece of tin to another by inoculation, and spreads very rapidly when the temperature gets below zero. After a very cold winter, 1867, some blocks of tin which were stored in the Custom House at St. Petersburg, mysteriously crumbled to a grey powder, and this on examination was found to be tin which had become "diseased." On pouring hot water over the metal it immediately returned to its original condition.

It would appear that all the malleable tin in the world, except on hot days, is in an unstable state, and that it is only some peculiar passive resistance which prevents it crumbling to powdered tin.

Tin exhibits a great tendency to crystallise. Thus if a bead of the molten metal be allowed to cool in air its surface becomes frosted into the crystalline form. Another illustration of crystallisation may be obtained by slightly attacking the surface of a sheet of tinplate with acid, when the beautiful pattern shown in the photograph—natural size—Fig. 368 can be obtained.

Iron sheets appear to have been first coated with tin to form tinplate in Bohemia during the year 1720, and from that date to the present the metal has been increasingly used for the coating of iron and steel goods.

Besides being used for coating purposes, it is used for the making of bronzes, solders, and many other different alloys. Also some of its chemical compounds are used in dyeing, enamelling, and other ways.

### The Metal Lead.

**Occurrence of Lead in Nature.** The metal exists in a very widely distributed form in Nature, workable deposits being found in most countries existing in all kinds of rocks.

There is about 0.002 per cent. of the earth's crust composed of lead, this being equal to, roughly, 1 part of lead to over 50,000 parts of the earth's crust.

The principal ore of lead is galena, which is a compound of lead and sulphur. In this form it is found in Shropshire, Derbyshire, and Flintshire. Another ore is carbonate of



FIG. 368.

Photograph of Spangles (Natural Size) on Surface of Tinplate after Slight Acid Attack.

lead, which is found in Spain, Australia, etc., and a third ore, sulphate of lead, is found in Anglesey.

Lead ores commonly contain silver, which is separated from the lead in the smelting operation.

**Properties.** Lead is a soft metal, which can be quite easily cut with a knife. The freshly cut surface exhibits a distinct metallic lustre of a bluish-grey character, but this quickly disappears and the surface, under ordinary conditions, rapidly oxidises. On account of this softness it is very weak, a wire  $\frac{1}{16}$  in. in diameter breaking with a load



of only about 30 lb., whereas a soft iron wire of the same diameter requires a pull of about 470 lb. to break it. •

The metal tends to form crystals as it cools down to the molten state, and the growth of lead crystals from solution can be easily brought about by plunging a strip of zinc into a solution of citrate of lead, when a tree-like form of lead crystals will "grow" about the strip of zinc.

The density of lead is 11.34, which means that lead is about eleven and one third times the weight of an equal volume of water. Its melting point is 327° C. When the metal is in the molten state, it is, of course, somewhat lighter, its density then being 10.64. For practical purposes in calculating weights one cubic foot of lead can be taken as weighing 710 lb., but when in the molten state 664 lb. ••

The metal can be readily rolled into thin sheets, and squirted or extruded under pressure either into wire or tubes.

**Spelter and Lead.** Galvanisers should be interested in lead, as all spelters contain portions of this metal, which not only affect the galvanising process, but also the resulting coat on wire or sheet. Commercial spelter usually contains about 1 per cent. of lead, but in some very impure spelters this may go up to 3 or 4 per cent. Lead and zinc have very little liking for each other, consequently the lead in spelter is usually found in the form of small isolated globules.

When spelter containing lead is in the molten state the globules of lead, being heavier than the molten zinc, and, not mixing with it, gradually sink to the bottom of the galvanising bath, and this is the cause of the accumulation of lead there found.

**Lead-tin Alloys or Solders.** In addition to being used for the purposes already mentioned lead forms some very useful alloys with the metal tin. These have some very remarkable properties from the point of view of melting at a low temperature. Thus if 36 per cent. of lead be mixed

with 64 per cent. of tin the melting point of the alloy is  $181^{\circ}\text{C}$ ., which is the lowest melting point that can be obtained from any combination of lead and tin.

The lowering of the melting point to  $181^{\circ}\text{C}$ . is interesting when it is remembered that lead itself melts at  $327^{\circ}\text{C}$ ., and tin melts at  $232^{\circ}\text{C}$ . If 1 part of lead be added to 1 part of tin, which forms common solder, the melting point is  $220^{\circ}\text{C}$ ., and if 2 parts of lead be added to 1 part of tin to form plumbers' solder the resulting melting point is  $260^{\circ}\text{C}$ .

There is, however, a very peculiar alloy known as "Rose's Fusible Metal," which is composed of 1 part of lead, 1 part tin, and 2 parts of bismuth, and has the extraordinarily low melting point of  $94^{\circ}\text{C}$ ., which is six degrees below the boiling point of water.

**Coating Other Metals with Lead.** Lead has such little affinity for other metals that it is somewhat difficult easily to put a coat of this metal on iron or steel, but if a small percentage of tin be added to the lead and a suitable flux used a coating can be applied.

Unfortunately, however, the metal itself is so soft that when it is applied to steel or iron it is quite easily scratched and the base metal exposed, and, then, as the lead is electro-negative to the iron, this rapidly assists the corrosion of the latter.

**Corrosion of Lead.** It has been previously mentioned that when pure lead is cut it shows a bright metallic appearance, but this rapidly tarnishes, or if exposed to the atmosphere quickly coats over with a skin of carbonate or oxide.

Fortunately, the skin which is formed, like those which form on copper and zinc, is not easily dissolved, and this is the real secret why lead offers resistance to atmospheric corrosion when used for roofing and other purposes.

Lead, too, on account of the resistance it offers to being

dissolved by the ordinary acids hydrochloric and sulphuric, is used for the lining of tanks, cisterns, etc.\*

It is rather peculiar that whilst this metal offers considerable resistance to being dissolved by the acids mentioned, it is easily dissolved by a weak acid such as vinegar (acetic acid). It is also dissolved by soft water, and for this reason should not be used as a lining for storage tanks for water of this kind. With hard water there is no danger, as a thin coating rapidly forms on the surface of the lead, whether it is in the form of storage cisterns or water pipes, which effectively protects the remaining portion of the metal from being dissolved.

### The Metal Copper.

**Properties.** It is the only metal which has a red colour, is very malleable, ductile, and tenacious. Its strength in the cast state is only about half that of iron, but when rolled, drawn, or hammered its strength and hardness rapidly increase, and when alloyed with other metals, it can be made almost as strong as steel. It is a little heavier than iron, the weight of a piece of copper of the same size as a piece of iron being about one-seventh greater. The metal is a much better heat and electricity conductor than iron. It has a fairly high melting point, this being  $1065^{\circ}$  C. Under ordinary conditions it offers considerable resistance to weather corrosion, and for this reason for many centuries has been used for the roof-coverings of mansions, churches, and important buildings. Although it offers great resistance to atmospheric corrosion, the metal is readily absorbed by vegetable and meat juices, and for this reason should not be used in the bare state for domestic utensils or for any other purpose in which it is likely to contaminate a liquid or food.

When iron or steel is dipped into a solution of copper sulphate, the copper from the solution is deposited on the iron. Unfortunately, this copper coating offers very little

resistance to the corrosion of the iron on account of the latter being electro-positive to the former; in fact the two metals being in contact actually accelerates the wasting away of the iron. If the copper on the surface is made more compact by rolling or drawing, it then offers a greater protection to the iron. If copper, however, is fused on to the surface of iron, to form either copper-clad wire or sheet, it gives a remarkable protection to the underlying iron. And if the coating is of appreciable thickness, the "life" of the material is very greatly enhanced.

**Welding of Copper.** Sheets or plates of the metal can be readily welded by the aid of the oxy-acetylene blowpipe, the metal being simply fused and a copper wire, containing a small amount of phosphorus or other de-oxidising substance, run into the joint. There is now produced a special de-oxidised copper sheet, plate and wire which gives excellent results in practice.

### **Alloys.**

Copper is considerably hardened when small portions of other metals are added to it. A good illustration of this is the copper coinage, which is comprised of 95 parts of copper, 4 parts tin, and 1 part zinc.

When copper is alloyed with zinc it is usually called zinc, and when with tin is known as "bronze." But these two kinds of alloys often contain other metallic or non-metallic elements to give them some special property.

**Monel metal**, which offers considerable resistance to atmospheric and acid attack, is composed of about 67 per cent. nickel, 28 per cent. copper, and 5 per cent. iron.

**Silveroid metal**, which gives a high polish and retains its lustre, is composed of 55 per cent. copper and 45 per cent. nickel.

**Tobin bronze** is composed of 58 per cent. copper, 39·4 per cent. zinc, 2·5 per cent. tin, and 0·1 per cent. iron.

**Duralumin** is composed of 94·4 per cent. aluminium,

4.5 per cent. copper, 0.95 per cent. magnesium, and 0.76 manganese. A German alloy used on airships is composed of 88 per cent. aluminium, 10 per cent. zinc, and 2 per cent. copper.

**Stainless steel** is iron containing 12.75 per cent. chromium and 0.65 per cent. carbon.

**Stainless iron** is similar in composition to the steel except that it contains only about 0.18 per cent. carbon. It is much softer than the steel.

The stainless steels require very great care when being worked red hot, as at a certain range of temperatures they tend to break up. Also, the stainless properties are only at their maximum when the metal is put into service in a highly polished condition.

**Staybrite** is iron which contains 18 per cent. chromium, 9 per cent. nickel, and 0.2 per cent. carbon. In sheet it is tough but workable and offers great resistance to atmospheric or acid attack. It is readily welded with the oxy-acetylene blow-pipe, but if it is to be used, subsequently, for vessels containing corrosive solutions, care must be taken to see that the vessel is annealed after welding at a temperature to bring about a uniform condition of the metal.

**Stalloy** is an iron which contains 4 per cent. of silicon. When rolled into sheets it is used in making electrical transformers and other types of machinery or plant. It is very hard and brittle to cut, but as it is generally used in the flat this is no great disadvantage.

**Yorkcalbro** is an alloy which contains 70 per cent. copper, 28 per cent. zinc, and 2 per cent. aluminium. It is used in the making of condenser tubes on account of the resistance to corrosion which it offers under the particular condition of working.

**Cupro-nickel**, which contains 70 per cent. copper and 30 per cent. nickel, has similar properties to the previous alloy.

**Nickel-silver** is composed of from 25 to 35 per cent. nickel, from 0 to 10 per cent. zinc, the rest being copper.

**Wood's Fusible Alloy** is composed as to 50 per cent. of bismuth, 25 per cent. lead, 12·5 per cent. tin, and 12·5 per cent. cadmium. A similar alloy is composed of 38 per cent. bismuth, 31 per cent. lead, 15 per cent. tin, and 16 per cent. cadmium.

## APPENDIX

*Specimen Examination Papers of the City and Guilds of London Institute, and the Union of Lancashire and Cheshire Institutes.*

STUDENTS of technical colleges and schools may obtain some idea of the kind of questions they are expected to answer to qualify for certificates in sheet and plate metal work, by a careful study of the examination papers that follow, and which were recently set by the examining institutions named above. ••

In some technical schools a large amount of practical work is done either in making actual articles or the building up of models in sheet metal that illustrate the underlying geometrical principles of pattern making. Some of this latter work is shown in Figs. 369 and 370, these being illustrations reproduced from *Workshop Practice* published by Sir Isaac Pitman & Sons, Ltd. The specimens photographed were made in one of the Lancashire technical schools.

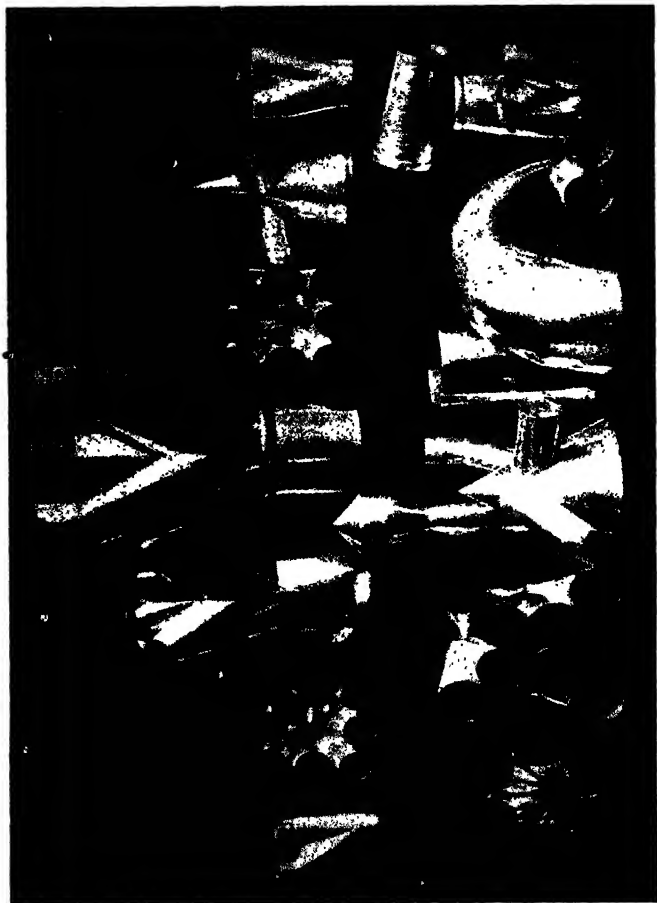


Fig. 369.





Fig. 370.

## CITY AND GUILDS OF LONDON INSTITUTE

## DEPARTMENT OF TECHNOLOGY

## METAL PLATE WORK

## Grade I

1. Find the cubic capacity of a rectangular vessel of internal dimensions 3 ft. by 2 ft. 6 in. by 2 ft. 9 in.

How many gallons will this vessel hold? (30 marks.)

2. A vessel is required to hold 60 gallons, and is to stand on a rectangular space 2 ft. 6 in. by 2 ft. What must be the height of the vessel? Ignore the thickness of the material of which the vessel is made. (40.)

3. Describe three different joints used in sheet metal work, giving reasons for the use of each different joint. (30.)

4. Write a short essay on solders and soldering, dealing with the composition and uses of hard and soft solders and the process of autogenous soldering. (30.)

5. Describe in detail how you would re-bottom a circular vessel made of sheet copper, so that when finished its original depth would be retained. (40.)

6. Describe the methods in general use for annealing (a) sheet iron, (b) copper. What is the specific gravity of each of these metals? (30.)

7. Draw to scale the patterns for the tapered tube forming a junction with a circular tube, as shown in Fig. 1. (40.)

8. Draw to scale the patterns for the frustum of a cone of the dimensions shown in Fig. 2. (30.)

9. Draw to scale the patterns for the cylindrical knee joint shown in Fig. 3. (30.)

10. Draw to scale the patterns for the cone and cylinder joint shown in Fig. 4. (40.)

11. Draw to scale the patterns for the base of a square chimney stack, the plan of which is shown in Fig. 5. The vertical height of the stack is 3 ft. (40.)

12. Draw to scale the patterns for the right cone intersected by a cylinder, as shown in Fig. 6. (50.)

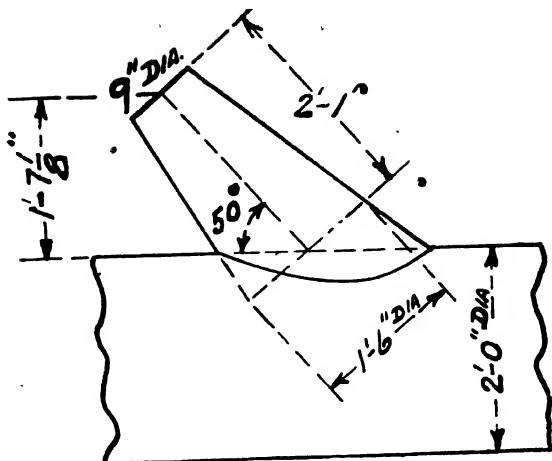


FIG. 1

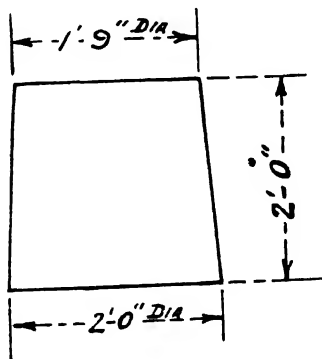


FIG. 2

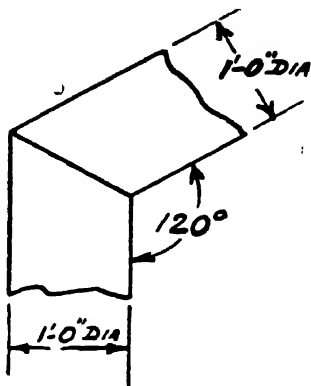


FIG. 3.

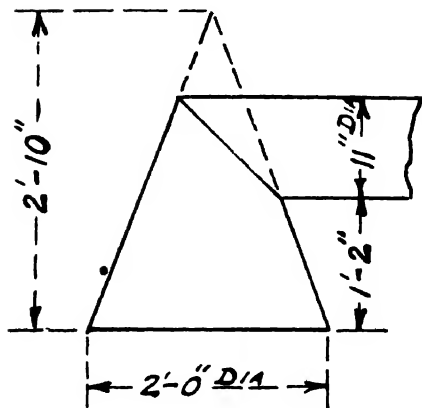


FIG. 4.

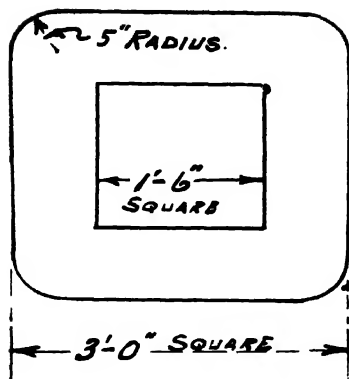


FIG. 5.

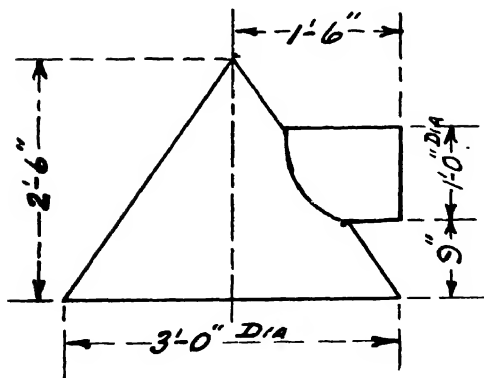


FIG. 6.

### Final Examination

1. Find the cubic capacity of a vessel of elliptical shape with the following internal dimensions: major axis 2 ft. 6 in., minor axis 1 ft. 8 in., height 2 ft. 1 in. (30 marks.)
2. Find the volume of a sphere 2 ft. 6 in. in diameter. (40.)
3. Compare (a) aluminium, (b) iron, (c) copper and (d) zinc in regard to specific gravity, ductility, malleability and tenacity. (40.)
4. Compare the composition and physical characters of the following fuels, giving reasons for the use of each in the various processes of metal plate work: (a) coal, (b) coke, (c) breeze, (d) charcoal. (30.)
5. Describe in detail the construction of the folding machine in general use in sheet metal work, and state its advantages as compared with folding by hand-work. Use sketches to illustrate your answer. (30.)
6. Name the constituent materials and the percentages of each in (a) bell metal, (b) gunmetal, (c) speculum metal, and (d) bronze coinage. (30.)
7. Draw to scale the patterns for the intersecting cylinders as shown in Fig. 1. (40.)
8. Draw to scale the patterns for the oblique piece of tapered trunking shown in Fig. 2. (40.)
9. Draw to scale the patterns for the hood, the plan of which is shown in Fig. 3. The vertical height of the hood is 2 ft. 6 in. (40.)
10. Draw to scale the patterns for the tapering Y pieces shown in Fig. 4. (50.)
11. Draw to scale the patterns for the dust cyclone casing shown in Fig. 5. (40.)
12. Draw to scale the patterns for the intersection of the sphere and cylinder shown in Fig. 6. Draw a development of the cylinder. (50.)

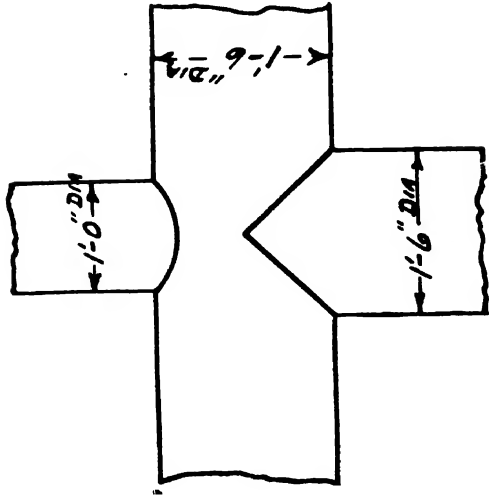


FIG. 1

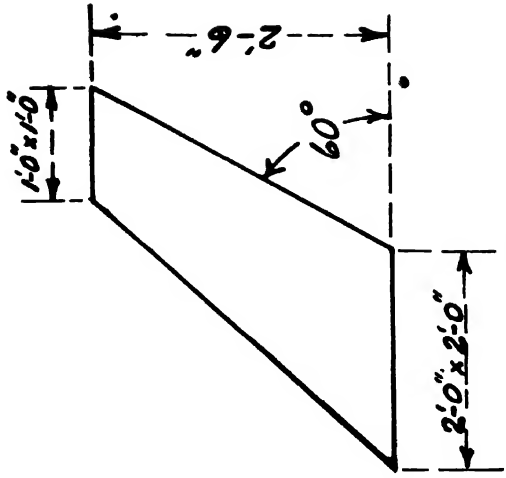


FIG. 2.

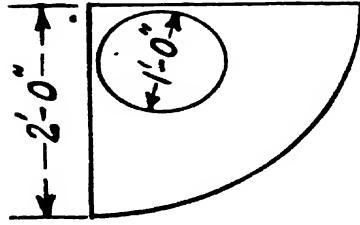


FIG. 3

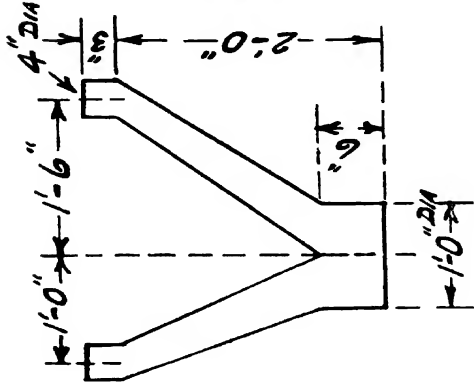


FIG. 4

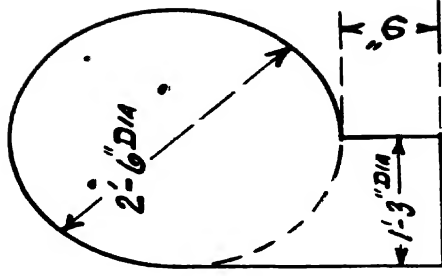


FIG. 6



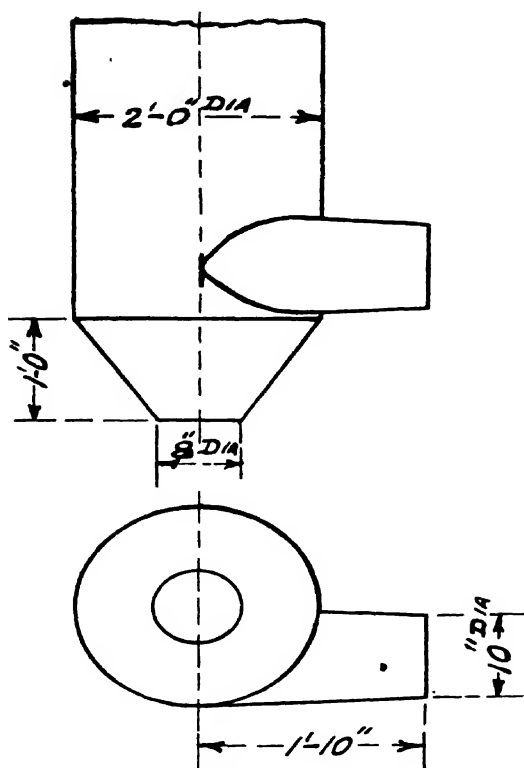


FIG. 5

## UNION OF LANCASHIRE AND CHESHIRE INSTITUTES

## SHEET AND PLATE METAL TRADES COURSE

## TRADE CALCULATIONS AND DRAWING

## First Year

1. Calculate the greatest number of strips, each 16 in. long by  $\frac{3}{4}$  in. wide, that can be cut from a sheet of iron 66 in. by 30 in. How many square inches of scrap will be left over?

2. What length and weight of 4-gauge wire will be required to wire around the tops of six dozen circular vessels of diameter 28 in. [100 ft. of 4-gauge iron wire weighs 14 lb.]

3. A cubical open-topped tank 4 ft. deep is formed of five plates of  $\frac{1}{4}$  in. mild steel, welded along the edges. (a) What will be the weight of the tank, assuming  $\frac{1}{4}$  in. plate weighs 10 lb. to the square foot? (b) How many feet of welding will be required? (c) How many gallons of water will the tank hold?

4. A roll of bright steel strip is 100 ft. long and weighs 80 lb. Four gross of pressings are blanked from the roll, these weighing 72 lb. What proportion of the roll has been lost in scrap? Calculate the weight of one of the pressings.

5. A V-shaped trough is 12 in. wide, 8 in. deep, and 8 ft. long. Calculate its weight, assuming that it is made of 16-gauge iron and has two stop-ends. [16-gauge iron sheet weighs  $2\frac{1}{2}$  lb. to the square foot.]

6. A plate is in the form of a rectangle 7 in. by 4 in. A rectangular hole 3 in. long is to be cut in the centre of the plate, its sides being parallel to, and proportional to, those of the plate. Set out the exact shape of the plate, full size.

7. Fig. 1 shows a sketch of a coal bucket whose body is formed of part of a cylinder. Set out patterns for the body and bottom, assuming that the bucket is to be wired around

the top, grooved down the back, and the bottom knocked-up.  
Scale: *one-quarter full size.*

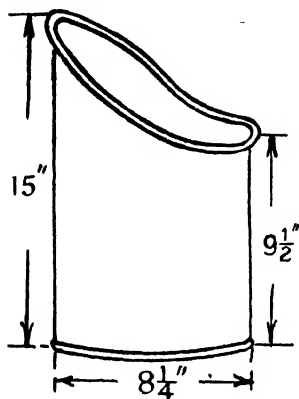


FIG. 1.

8. A conical vessel is of the dimensions shown in Fig. 2.  
Set out patterns for the body and bottom to a scale of one-quarter full size, making allowances for wiring, grooving, and knocking-up.

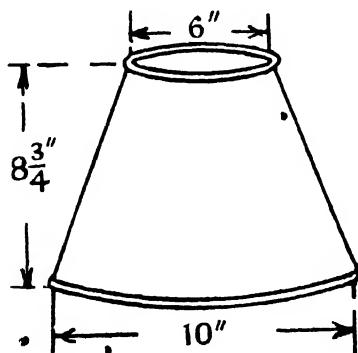


FIG. 2.

**Second Year**

1. A sheet of copper weighs 40 lb. After 24 pieces of the same size have been cut from the sheet, it is found that 8 lb. of scrap is left. Calculate (a) the weight of each piece, and (b) the weight of scrap as a percentage of the weight of the whole sheet.

2. Calculate the weight of 24 bars of mild steel, each 12 ft. long, 3 in. wide, and  $\frac{1}{4}$  in. thick, having given that a cubic foot of mild steel weighs 489 lb.

3. Calculate the length of 8-gauge wire required to go around the tops of two gross of oval vessels, each 25 in. by 17 in. Also work out its weight, assuming that 100 ft. of 8-gauge wire weighs 7 lb.

4. Calculate the weight of an elliptical plate is 6 ft. long and 4 ft. wide. The plate can be taken as weighing 10 lb. to the square foot.

5. A wooden vat whose inside dimensions are 10 ft. long, 3 ft. wide, and 3 ft. deep is to be lined with zinc. Calculate the weight of zinc required, allowing for laps and a 3 in. turn over around the top, if a sheet 8 ft. by 3 ft. weighs 20 lb.

6. A dome, which is in the form of an octagonal pyramid, is 6 ft. along the base of one sector and 9 ft. up the middle of the slope. It is to be covered with "Staybrite" sheet. Calculate the number of square feet required, allowing 10 per cent. extra on the net area for laps and scrap.

7. Set out the exact shape of the sectors in Question 6 to a scale of  $\frac{1}{4}$  in. to the foot. Also mark out the angle which the sloping sector makes with the horizontal.

8. A sketch of a conical jug is shown in Fig. 1. Set out patterns for the body, lip, and handle to a scale of one-half full size, making allowances for wiring, etc.

9. A sketch (Fig. 2) is shown of a right-angled elbow for a 5 in. half-round gutter with a  $\frac{1}{2}$  in. flange turned inside. Set out a pattern for one of the branches to a scale of one-half full size.

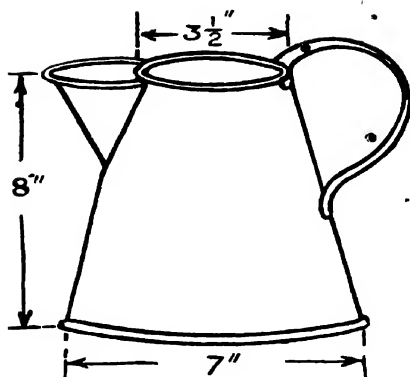


FIG. 1.

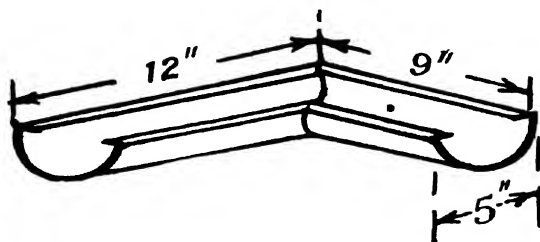


FIG. 2.

**Third Year**

1. A 50 ft. length of  $3\frac{3}{4}$  in. wide, 16-gauge, bright steel strip is used to press cut 165 discs,  $3\frac{1}{2}$  in. diameter. Calculate the weight of the strip, discs, and scrap respectively. The weight of 16-gauge mild steel is  $2\frac{1}{2}$  lb. to the square foot.

2. A 200 ft. length of 24 in. diameter mild steel pipe  $\frac{1}{8}$  in. thick is made up in 3 ft. lengths with 3 in. slip-in joints. There is one longitudinal seam with a  $1\frac{1}{2}$  in. overlap. Calculate the total weight of the pipe. Plate  $\frac{1}{8}$  in. thick weighs 5 lb. to the square foot.

3. A copper cylinder, of length 3 ft. and diameter 12 in., has a flat bottom and a hemispherical dome. It is made of plate weighing 4 lb. to the square foot. Calculate its weight, neglecting laps.

4. How many gallons of water will the cylinder referred to in Question 3 hold?

5. A tapered hopper is 10 ft. square at the top and 2 ft. square at the bottom, its vertical depth being 12 ft. It is made of  $\frac{1}{2}$  in. plate, all joints being electrically welded. Calculate its weight. Mild steel plate  $\frac{1}{2}$  in. thick weighs 10 lb. per square foot.

6. Calculate the capacity in cubic feet of the hopper referred to in Question 5. What would be its capacity from the top to the half depth, and from the half depth to the bottom, respectively?

7. An oval equal-tapering article is 36 in. long by 24 in. wide at the top, and 22 in. long at the bottom, its vertical depth being 8 in. Set out a pattern for one-half of the body, to any convenient scale.

8. Fig. 1 shows a sketch of a rectangular-shaped pan made out of one piece of sheet metal. The sides and ends are quarter circle in shape. The top is 14 in. by 10 in. and the vertical depth 3 in. The pan is to be wired around the top, the corner joints being either soldered or welded. Set out a pattern for the whole pan to any convenient scale.

9. The plan and elevation of an equal-tapering article are shown in Fig. 2. Set out a pattern for one-half of the body, to any suitable scale, arranging for the joints to be down the two ends as shown by the dotted lines.

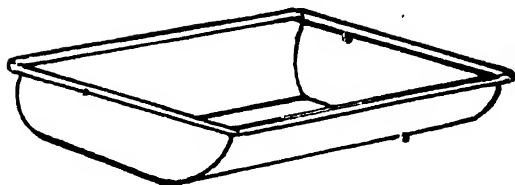


FIG. 1.

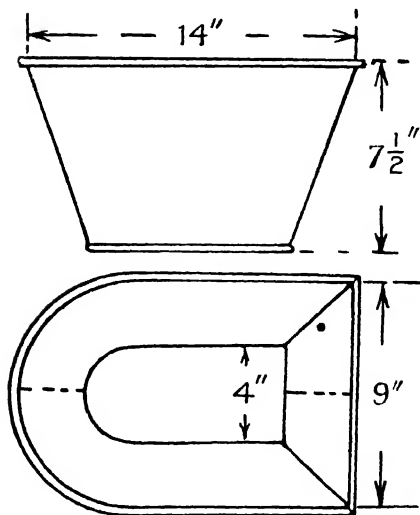


FIG. 2.

**UNION OF LANCASHIRE AND CHESHIRE INSTITUTES**  
**SHEET AND PLATE METAL TRADES COURSE****TRADE PROCESSES AND MATERIALS****First Year**

1. There is a certain stiffness in some sheet metals, particularly tinplate, which it is necessary to remove by "breaking" to avoid crinkling during bending. How is the operation of "breaking" carried out?

2. Explain the kind of test which should be applied to samples of black mild steel sheet to ensure that they possess good "working-up" properties.

3. In rolling or working sheet copper it becomes hard. Explain how it can be softened and cleaned afterwards.

4. Explain how the end of a soldering bit should be prepared and tinned. Why is it necessary, at times, to re-tin the point of a soldering iron?

5. Give the compositions of solders to be used for soldering tinplate and zinc, and explain how good joints can be made in sheets of these materials.

6. (a) Describe, with sketches, how grooved and knocked-up seams are made. What precautions have to be taken to ensure tight joints?

(b) Describe, with sketches, the various kinds of riveted joints used in plate work, and state what is done to make the seams watertight.

7. Defects are sometimes found on articles where the side seams meet the wiring or knock-up joint on the bottom. Explain what these defects are and how they can be avoided.

8. A circular vessel is to be wired around the top with  $\frac{1}{16}$  in. diameter wire, and jointed down the side with a riveted overlap of  $\frac{3}{4}$  in. The sheet is  $\frac{1}{8}$  in. thick. Mark out the shape of the notch.

9. (a) Describe, with sketches, the tools used in making grooved, knocked-up, and riveted joints in sheet metal.

(b) Describe, with sketches, the tools generally used in connection with light plate work.

10. A great number of articles are now coated with zinc as a protection against corrosion. Explain one of the ways by which this process is carried out.



**Second Year**

1. Give the composition of one of the sheet brasses. How do the properties of this alloy differ from those of the metals of which it is composed?

2. Write down the names of the four metals iron, zinc, lead, copper in the order of their strengths. Also state which of these metals has the highest melting point, and which the lowest.

3. Explain the methods adopted for the cleaning or pickling of sheet iron, which is afterwards required to be either tinned, galvanised, or plated.

4. Sheet-metal articles are jointed by either grooving, brazing, riveting, or welding. Give an example of the use of each of these methods, and the reason for its adoption.

5. Sheet-metal articles, or parts of articles, are sometimes formed by stamping, pressing, or spinning. Give examples of the application of *two* of these methods.

6. Why is it necessary to use a flux in soldering and brazing? What defect is found in a joint when the flux has not penetrated in between the surfaces of the metal?

7. What precautions are necessary in working up galvanised sheet? Under what circumstances is it an advantage to make an article out of black sheet and galvanise it afterwards?

8. In planishing sheet metal or flattening plate, surface defects may be set up. What is the nature of these defects, and how may they be avoided?

9. (a) Make clear sketches of a cramped joint and also of a scarfed joint used in brazing iron and copper.

(b) Make neat sketches of the various forms of rivets which are used in plate work, and give an example of the use of each form.

10. (a) A disc of sheet copper of diameter 10 in. has to be worked up into a hemisphere. Explain how this should be done so as to avoid cracking around the edge or local thinning of the sheet.

(b) Explain how a ring flange should be acetylene-welded on to the end of a 15 in. diameter plate steel pipe.

### Third Year

1. State the various factors which should be taken into consideration when deciding upon the kind of metal, and thickness of sheet, which should be used for a particular kind of article. Name *three* articles in which different materials are used.

2. Give particulars of any defects of manufacture which may be found in sheet or plate metals.

3. Name some of the defects due to bad workmanship which you would look for when examining sheet metal work. Explain how such defects may arise.

4. What is meant by the terms "tenacity" and "malleability" of metals? Write down the following metals in the order of their tenacity and malleability respectively: mild steel, aluminium, lead, copper.

5. Explain the methods adopted for the bending of brass and copper tubes, so that they may not flatten or otherwise get damaged.

6. Give examples of the use of the following alloys for sheet-metal articles: duralumin, monel metal, "Staybrite." State what particular properties account for the selection of these particular materials.

7. Coke, gas, and electricity may be used as sources of heat for soldering and other purposes. State the advantages and disadvantages of each.

8. For use in exposed positions both sheet and plate metals have their surfaces treated to resist corrosion. Give particulars of the various processes that are in use, and compare their advantages and disadvantages.

9. (a) Describe, with sketches, a swaging machine, a spinning jenny, and a folding machine used in working or forming sheet metals.

(b) Describe, with the aid of sketches, the construction and operation of an oxy-acetylene cutter.

10. (a) Very light sheet metal is now being welded either with a small blowpipe or by spot welding. Give a description of these processes.

(b) Give particulars of tests on specimen welds that would convey some idea of the quality of work to which a welder on an actual job could be expected to conform.

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